Advanced Pressure Garment Space Suit Sizing Considerations

Christine N. Jerome[1]
NASA Johnson Space Center/Jacobs, Houston, Texas, 77058

and

Richard A. Rhodes[2]
NASA Johnson Space Center, Houston, TX 77058

and

Donald H. Campbell II[3]
NASA Johnson Space Center/KBR HHPC, Houston, Texas, 77058

Fitting a space suit to a person could be considered an art form. Establishing a repeatable fitcheck process to accommodate the full anthropometric range of test subjects for a single suit design is a critical process to be able to prove suit functionality. Suited test subjects can have different preferences on how they fit inside a suit, and different suited test environments can lead to differences in certain suit sizing accommodations. Throughout this paper, the process of achieving an acceptable suit fit for test subjects will be discussed, along with sizing considerations for changes in suit design and test environments. Lessons learned from the Exploration Extravehicular Mobility Unit (xEMU) will be used to describe specific examples, along with key takeaways from additional NASA prototype mobility space suits. The suit fitcheck process starts with utilizing the anthropometric measurements of a test subject to evaluate their relation to the dimensions of space suit hardware to create a predicted suit size configuration. From here, subjective comments and test team observations drive iterations to the suit sizing configuration to culminate in an acceptable suit fit for performance of further test evaluations. Understanding the relation of subjective comments to their impact on altering suit sizing is critical in establishing an acceptable suit fit.

Nomenclature

ABF	=	Anthropometric and Biomechanics Facility
ARGOS	=	Active Response Gravity Offload System
CAD	=	Computer-Aided Design
DIDB	=	Disposable In-suit Drink Bag
EMU	=	Extra-vehicular Mobility Unit
EVA	=	Extra-Vehicular Activity
EVVA	=	Extra-Vehicular Visor Assembly
HUT	=	Hard Upper Torso
LCVG	=	Liquid Colling and Ventilation Garment
MAG	=	Maximum Absorbancy Garment
NBL	=	Neutral Buyouancy Lab
TCU	=	Thermal Comfort Undergarment
WBH	=	Waist Brief Hip Assembly
xEMU	=	Exploration Extra-vehicular Mobility Unit
xPGS	=	Exploration Pressure Garment Sub-system

[1] Space Suit Engineer, Space Suit and Crew Survival Systems Branch, NASA Johnson Space Center
[2] Advanced Suit Team Lead, Space Suit and Crew Survival Systems Branch, NASA Johnson Space Center
[3] Advanced Suit Team Deputy Lead, Space Suit and Crew Survival Systems Branch, NASA Johnson Space Center

II. Introduction

Properly fitting a subject into a space suit is a critical task that plays a large role into acceptable task performance. Achieving this acceptable fit is a process that has been long performed, and often iterated. When working with human test subjects, the subjective perception of fit varies for each person, so there is no perfect algorithm that can perfectly fit everybody. This paper will go into the current process that the Advanced Suit Team at NASA's Johnson Space Center (JSC) uses to provide subjects with a comfortable and functional fit in their space suit. This process was originally derived from the same processes used by the Extravehicular Mobility Unity (EMU) space suit team, but adapted to apply to planetary space suits and advanced mobility prototypes. This paper primarily uses the Exploration Extravehicular Mobility Unit (xEMU) for references. However, the processes described and lessons learned apply to most planetary space suits. Additionally, the process for achieving an acceptable glove sizing configuration can be extensive, thus it will not be discussed in detail in this paper.

III. Acceptable Suit Fit Process

There are multiple iterative steps in achieving an acceptable fit within a space suit. Figure 1 illustrates at a high-level the flow of these steps and the sequence in which they are taken. Each step will be further broken down later in this paper. The fit process starts off with taking anthropometric measurements of a test subject. There is a minimum set of measurements necessary for predicting sizing. Once measurements are taken, those can be utilized with known measurements of suit hardware, and a predicted suit sizing configuration can be calculated. Predictive models for the xEMU were initially based off of the linear lengths measured from CAD models of the spacesuit in key positions. Feedback from fitchecks have fed back into the prediction algorithm to improve the fit predictions.

The suit hardware is configured into this sizing prediction, and the in-person fitcheck event can be performed. Often, it is best practice to have alternate sizes of certain suit components available at a fitcheck. It can be useful to allow test subjects to feel longer and shorter sizes from the prediction to better inform their sizing and comfort feedback. Throughout this event, it is crucial to ask specific fit and comfort related questions and make relevant sizing changes to mitigate future hot spots or pressure points and improve fit for task performance. Subjects should perform several mobility tasks and be polled about contact points, glove and foot indexing, and areas of discomfort during task performance. This event may require multiple iterations, as the way the space suit fits the subject in one suit component can impact fit in a seemingly unrelated suit component (i.e. arm length can impact hip indexing) as the space suit needs to be considered one whole suit system. It is important to note that this initial fitcheck is typically performed in a 1-G environment, with specific accommodations made to evaluate the future planned test environment/s. For example, in the ARGOS and NBL test environments the suit is essentially being lifted, while the 1-G mass of the person is holding the suit down. To evaluate the suit fit for these environments the subject may be suspended to evaluate the fit in that configuration.

To finalize the fit process, when subjects first conduct a test in a new test environment, it is crucial to validate their suit sizing configuration for the new environment. This is particularly true when altering the gravity level, as this causes the subject-to-suit interaction to change. Thus, before performing additional test objectives, subjects are asked to perform specific mobility tasks and are questioned on their fit and comfort prior to continuing the test. It is also important to follow up with subjects throughout the test as hotspots and pressure points can emerge with time and changes to suit configuration can be made to mitigate issues.

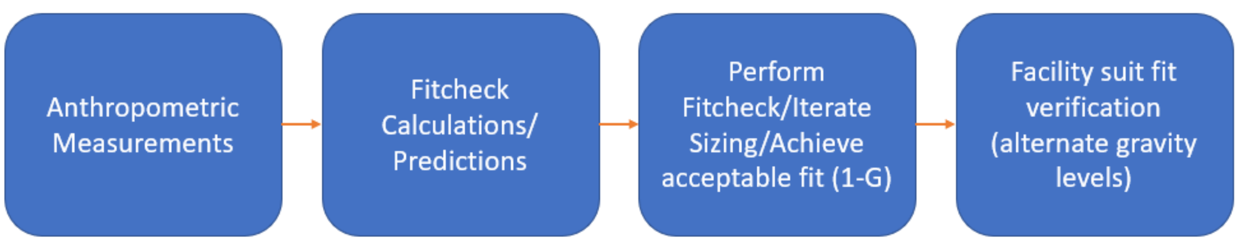

Figure 1. Suit Fit Process

IV. Test Subject Measurements

To start off the process of being fit into a space suit, suit engineers engineers create a baseline starting point in the form of anthropometric measurements of the subject. Depending on the space suit and the design features of the suit,

Table IV-1. Anthrompometric Data Collection

STATURE:
MID-SHOULDER HEIGHT:
VERTICAL TRUNK DIAMETER RIGHT
VERTICAL TRUNK DIAMETER LEFT
INTER-FINGERTIP MEASUREMENT:
INTER-WRIST MEASUREMENT:
INTER-ELBOW MEASUREMENT:
CROTCH HEIGHT:
KNEE HEIGHT:
CHEST BREADTH:
EXPANDED CHEST DEPTH:
HIP BREADTH:
CHEST CIRCUMFERENCE:
WAIST CIRCUMFERENCE:
THIGH CIRCUMFERENCE:
BICEP CIRCUMFERENCE:
HEAD CIRCUMFERENCE:
MIDDLE FINGER LENGTH LEFT:
MIDDLE FINGER LENGTH RIGHT:
CIRCUMFERENCE LEFT:
CIRCUMFERENCE RIGHT:
HAND LENGTH LEFT:
HAND LENGTH RIGHT:
CIRCUMFERENCE LEFT:
CIRCUMFERENCE RIGHT:
FOOT LENGTH
FOOT BREADTH

different subsets of measurements may be helpful. Table IV-1 displays the list of anthropometric measurements found to be most useful for NASA planetary suits, but there can be variations in this list for alternate space suits[1].

There are two primary methods of collecting this data. Most traditionally, trained suit team personnel will manually use an anthropometer and measuring tape to gather the data. More recently, a collaborative effort with the Anthropometric and Biomechanics Facility (ABF) has been able to perform a laser scanning session of test subjects to digitally place markers and measure between the necessary points. Both are acceptable forms to be used for predicting suit sizing. Manual measurements are often more reliable in areas in which it can be challenging to get an accurate marker placed, such as crotch height and vertical trunk diameter.

V. Fitcheck Predictions

In addition to having anthropometric measurements, it is essential to understand the impact the hardware has on this process. Just as measurements are needed for subjects, measurements are needed for each hardware component to create the relationship between the humans and the hardware.

The initial modeling of the hardware component length was based on CAD dimensions of the suit. These CAD dimensions, along with the subject anthropometry and assumptions about the indexing and fit of the subject within the suit, are used to estimate the right size of components, size of softgoods, sizing ring placements, cam positionings, and gloves sizes to be used to provide the best fit for the test subject. For EMU, the average lengths of actual available serial numbered hardware (softgood components) is used to do predicted sizing where CAD measurements aren't available[3].

VI. Fitchecks and Achieving Acceptable Fit

Now, subjects are ready to perform a fitcheck. It is critical to keep in mind the following when performing fitchecks:

- Each subject will have different preferences on how they fit. This is similar to clothing size preferences. Some subjects prefer a snug fit, while others prefer a little more room. Each subject will have their rationale as to why, but this is part of why fitchecks are essential. Additionally, subjects preferences will change over time as they learn more about the suit and the environment that they are operating in.
- Body composition can vary subject to subject. Three different subjects could have the same chest circumference, but they could have different bone builds, different muscle mass, etc., leading to different preferences in their sizing configuration. That shows why the anthropometric measurements are merely a starting point, and only fitchecks can establish acceptable sizing.
- Hardware manufacturing is not perfect. No two components are the exact same length. If enough inconcistencies are added up, sizing configurations can vary test event to event. EMU takes this into consideration with several components and makes adjustments based on each individual serial number of item being used, to provide a more consistent fit to crew[3].
- This process relies on subjective feedback, and the more subjects are encouraged to provide comments, the better the chance at achieving an acceptable suit fit[1]. Enunciating specific feelings and sensations can be difficult and contradictory. It is critical to maintain compassion and understanding when trying to refine the suit configuration.

- Being in a spacesuit can be overwhelming for new test subjects. It is very important to ask clear and specific questions about the contact points, indexing, and range of motion to enable better communication and understanding of fit and comfort issues[2].
- It can be challenging for a test subject to know how the suit should feel until you've had a chance to evaluate multiple sizes and learned how it shouldn't feel. Providing variability in the fit during the fitcheck can allow the subject to learn more about the suit and provide more informed feedback to the suit test engineer.

Subjects start the fitcheck event by changing into their predicted ancillary hardware, i.e. maximum absorbancy garment (MAG), thermal comfort undergarments (TCU), liquid cooling and ventilation garment (LCVG), socks, headbands, etc. It is important to wear the same articles as would be worn during a primary test event to verify no issues with comfort and mobility in the accepted suit configuration. Once the subjects are wearing their ancillay and LCVG, fit can be verified in these components. Subjects should be able to bend over and move their arms and legs around without pulling tight lines in the undergarments or in the LCVG, especially in the vent ducts. If there are issues, correct as needed and record differences prior to suit donning.

Now, subjects are ready to don the suit. The suit is installed in the donning stand for suit donning and doffing, which holds the suit via attachment points around the waist and can be set at different heights to accommodate all subjects. To start the donning process, subjects sit on stairs or bench seat at the suit hatch opening and connect the LCVG connectors to the suit. Next they lower themselves into the suit and move their arms and head into the suit's upper torso. Once subjects are seated in the suit, with their feet in the boots and arms and chest have donned the hard upper torso (HUT), shoulder strap length can be evaluated. Shoulder straps are present to assist in carrying the load of the suit, as well as for subject indexing in the HUT, and head placement in the helmet. In suit sizing, the term indexing is used to describe the relevant positioning of a space suit component to a human body location. Subject shoulders need to be somewhat centered in the shoulder openings, with at least approximately 1" of spacing between the shoulder and the top of the scye bearing, to ensure no hard contact between the two can occur. Shoulder strap length is often iterated on throughout the event. There is no way to change the distance between the suit's shoulders and the helmet of the suit, so the shoulder strap length is set to balance good head positioning and visibility against good shoulder positioning and comfortable range of motion. Seeing the head placement and shoulder mobility once pressurized and out of the donning stand can lead to desired changes in strap length.

With shoulder straps configured as desired, the hatch can be closed. Once complete, insight into HUT fit can be achieved. Unpressurized fit can differ from pressurized fit, but asking questions while unpressurized can help minimize pressure cycles on subjects. With the HUT closed, subject's should be comfortable taking a full breath. They will be working hard on EVA; taking deep breaths will be critically important. Subjects also shouldn't have excess negative space in the HUT. For smaller subjects especially, space can be taken up with back padding as necessary. It is beneficial to be positioned further into the chest and helmet to achieve optimal visibility, than to add padding to the front. Of course, if there is chest discomfort, that can be addressed as needed. Prior to pressurizing, it can also be useful to check if any insight can be gained into arm and leg length. This can often feel different with pressurization, so fine-tuning adjustments won't be made, but if either length prediction is significantly off, i.e., subjects can't straighten their arms or legs, that is a good time to resolve the issue.

Following pressurization, before egressing the donning stand, it is critical to verify the suit is in an acceptable stand-alone configuration before walking around in 1-G. Walking in 1-G with poor suit fit can risk injuries and discomfort to the test subject. Thus, while remaining in the donning stand, placement of shoulders, elbows, crotch, and knees can be preliminarily evaluated. It is also good to reassess ease of breathing questions, and if any discomfort is present. Since the suit is now pressurized, the more information gathered before depressurizing to make adjustments, the better. For example, if the subject can take a full breath now and have no contact with the back of the hatch, it can be beneficial to assess arm and leg length before completing the pressure cycle to determine if additional adjustments can be performed. It is possible that adding additional padding may impact subject comments on arm and leg length; it will be important for the test engineer performing that fitcheck to take that into account when assessing that fit. One way to take this into account is for engineers to pose questions differently, and suggestions can be made to the subjects to adjust their posture accordingly to better assess fit. For example, in this case, if the subject is straightening their arms fully, is the front of their chest still in contact with the disposable in-suit drink bag (DIDB), or do they have to move their chest aft to achieve full arm reach?

When assessing arm length, have the subject perform multiple positions, specifically a T-pose, then fully extend both arms in front of their shoulders, then bend their arms into their nominal work space, see Figure 2. In each pose, assess fingertip and finger-crotch pressure points, any additional hot spots, as well as subjective and tactile feedback on elbow positioning. Subjects can also reach their arms overhead and evaluate if they have any hard contact with the shoulders and the scye bearing. If they're getting hard contact on the top, that could indicate the shoulder straps are too loose, and if there's hard contact on the bottom of the opening, the shoulder straps could be too tight or there could be another problem with the suit length. It can also be beneficial at this time to provide a mirror for subjects to watch themselves articulate the joints, and give them time to practice moving the shoulder, elbow, and wrist joints for familiarization. More practice and more experience enables the subject to be a stronger performer. Subject's head and chest positions should generally be able to stay in the same position in each posture and while moving their arms around. If they're having to move their chest backwards in the HUT when their arms are stretched in front, the arms are likely too short. Subject's will likely experience different levels of fingertip pressure with outstretched arms compared to when working in their nominal work space. Subjective preferences will have to be considered for optimal sizing.

Figure 2. Subjects assessing arm length.

When performing a fitcheck in a 1-G environment, it is useful to assess the arm sizing whilst still installed in the donning stand. Once the subjects are standing on their own and bearing the full weight of the suit, their shoulders are under additional strain compared to an offloaded environment. Thus, performing the different arm assessment when the shoulders aren't bearing the weight of the suit will provide more realistic feedback, and reduce strain, and possibly injury for the subject.

While the subjects are still in the donning stand and getting familiar with the arm joints, head placement can be observed. Head placement can change significantly based on the posture of the subject. When in the donning stand, the subject can "sit" into the brief and their head could be low in the helmet in this position. Alternatively, if the subject has their legs fully straightened out below or slightly in front of them, they will show a more realistic head position for once they exit the donning stand. Though the former posture is less realistic, it still provides valuable information.

When the subject will be performing tasks, their hips should be well indexed into the brief of the suit, to best utilize the mobility joints in the brief. Thus, if they are "sitting" into the suit in the donning stand and there is approximately a >2 inch delta in their head and shoulder positioning between a sitting and a standing posture, that could indicate the hip joints on the suit will not be aligned with the subject's hip joint. This sensation for the subject can be casually described as the feeling of wearing "saggy britches" or feeling like they need to pull up their pants. However, a balance is needed. It is also not ideal for the subject to have an overly indexed hip joint and have hard contact between the brief hardware and crotch of the subject. That can become uncomfortable, particularly over long tests. Assessing the need for changes to waist length is best performed outside of the donning stand.

If the subject is showing a high head position in the donning stand with fully outstretched legs, several critical elements should be considered. Shoulder strap position could be too loose. The straps position subject shoulders, so if those aren't properly places, their shoulders and head placements could both be too high. Their waist sizing elements could be too short, thus pushing their torso high into the suit. Finally, the suit length in the total, primarily leg length, could be too short, also pushing their legs and torso high into the helmet. Head placement can also be assessed outside of the donning stand, though high head placement issues will likely be exaggerated outside of the stand in a 1-G environment, and low head placement issues could be hidden, due to excess weight on the subjects shoulders compared to an offloaded test environment. See Figure 3. Differences in head placement. Low (left) and high (right) for examples of low head placement with the chin level with the bottom of the neck ring and high placement with the top of the head touching or near the top of the helmet.

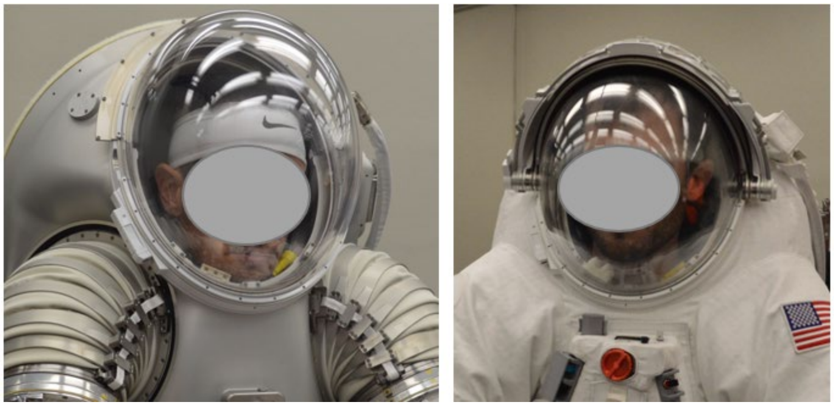

Figure 3. Differences in head placement. Low (left) and high (right)

Leg lengths are best assessed with a combination of questions inside and outside of the donning stand. The donning stand height is typically best set to just short of the length of the suit to assist subjects in donning and doffing the stand. Thus, subjects usually won't be able to fully straighten their legs below them. Either lift the subject into the air using the donning stand, or instruct them to kick out their heels in front of them, in a slightly piked position, and straighten their legs, see Figure 4. This position will also assist in evaluating the hip/brief indexing. While in this position, you can evaluate how much the subject is raising out of the brief when they go from "sitting" to "standing." They should be able to fully straighten their legs, while also feeling contact with the shoulders straps, and maintaining a nominal head placement in the helmet. They should not feel compressed in this position. They should also be polled on if they are feeling any crotch contact in this position as well. Light to no contact should be expected in the crotch.

Next, they can kick their heels up behind them while being held up by the donning stand, see Figure 5. While in this position, prompt subjects to describe the relative distribution of weight between feet, crotch, and knees. Ideally, the load distribution should be balanced equally between these locations. If the knee load is light, the length between the crotch and the knees should be shortened, or vice versa for heavy contact, while also balancing the contact on the crotch.

If able to make adjustments to the sizing at any point without pressurizing, reconfigure as able and reassess. This works best with cam mechanisms on the suit. If adjustments can't be made without depressurizing, discuss with subjects on their ability to egress the stand with this configuration. Prior to egressing the donning stand, assess their risk of injury and time efficiencies for the fitcheck. If there are major changes that need to occur, consider implementing those prior to having the subject walk in their suit configuration. The heels kicked up behind the subject method is most applicable when a subject will be fully offloaded for extended periods of time, such as NBL micro-gravity testing.

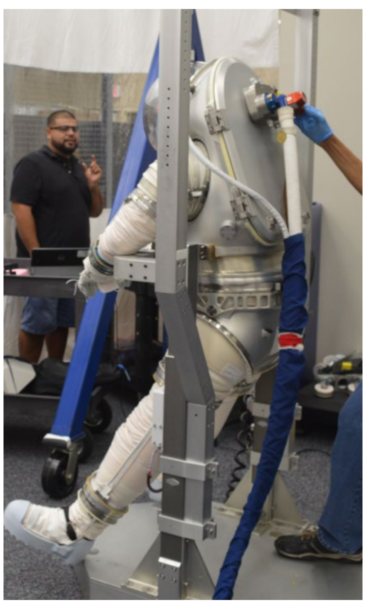

Figure 4. Pike position with straight legs to evaluate leg length, hip indexing, and shoulder straps.

Figure 5. Heels kicked up to assess pressure between knees and crotch.

If an acceptable suit configuration is in place, assist the subject out of the donning stand and give them time to perform a couple walking steps. As always, assess any pressure points or hotspots the subject is feeling. Subjects can be prompted to discuss the "shoulder to heel" length of the suit. Are they feeling excess or hard pressure on the bottom of their heel or their shoulders, keeping in mind the weight of the suit will feel like a lot of pressure on their shoulder straps. Subjects should be able to shrug their shoulders and not feel overly compressed in the suit, while some movement can be observed in the suit.

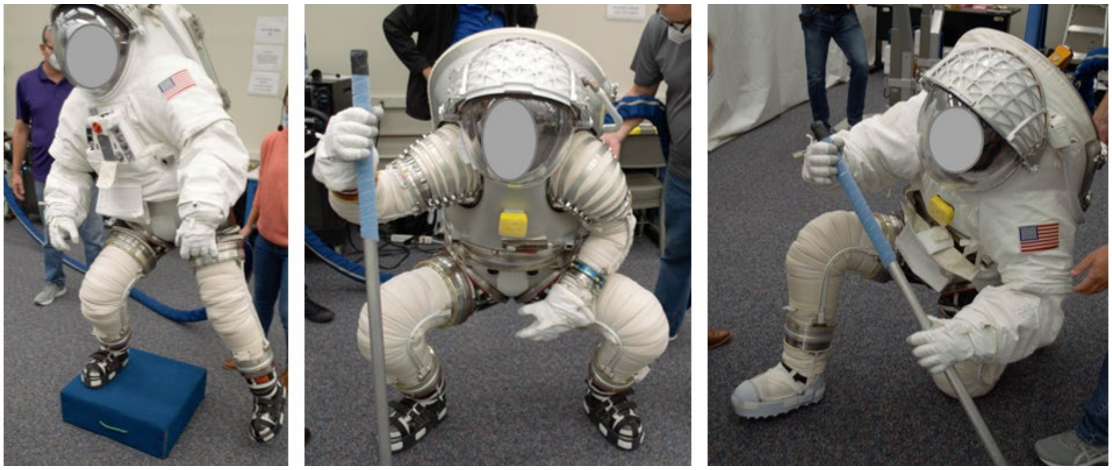

Figure 6. Subject performing mobility tasks during a fitcheck. Box step ups (left), squat (center), single leg kneel (right).

Table VI-1. Mobility Tasks for Fitchecks

Walking
Side-stepping up and over a box
Step up and step downs from a box
Squat
Single leg kneel

Subjects should individually isolate each mobility joint in the suit to evaluate subject indexing and any pressure points that can be mitigated. It is also beneficial to perform the mobility tasks listed in Table VI-1. See Figure 6 for examples of mobility tasks. Throughout all of these tasks, subjects should be prompted for comments on pressure levels (none/little/moderate/heavy) for any areas of concern, including but not limited to knees, shins, heels, crotch, and shoulders. Do they feel like their suit joints are breaking or bending where they should? Often, subjects may have excessive heel slippage when performing these tasks. Further questions regarding ability to shift balls of the feet side to side versus the heels should be prompted. A side to side heel shifting could indicate the need for additional padding or a smaller boot size, whereas vertical heel slippage could indicate a leg length issue or the need for indexing padding in the knee or heel areas.

This is also a good time to assess hip indexing. Subjects should be propted to comment on how much crotch contact they are feeling while walking around, while in the bottom of a squat, and in the bottom of their kneeling posture. Ideally, little to no contact should be felt walking around in 1-G, but could be more expected in the bottom of a squat or kneel. With this contact point, it is important to note that this is the best case gravity condition, and any contact felt in 1-G will worsen in an offloaded test environment. Thus, verifying the little to light contact is felt in 1-G is key. On the other hand, their hips should still be well indexed into the brief to allow for optimal placement of the joints and for efficient joint movements. This is the best time to assess the "saggy britches" phenomenon and adjust waist length as needed. Subjects shouldn't feel like they need to pull up their pants when approaching tasks. This indicates the waist is too long or if their head is high, they could need additional length in their waist and/or legs.

Additionally with leg length, a quick indicator for long legs is an "S" shape showing in their legs. This typically comes with pressure either in the back of the knees, front of the shins, or both. Figure 7 shows this "S" shape in the legs. Subjective comments on intensity of leg contact points is critical to know if the legs are too long, as some "S-ing" is due to being in a 1-G lab environment caused by the weight of the suit. "S-ing" may be minimized when in an offloaded environment.

Once comfortable with the information gathered on suit fit, the subjects can be directed back to the donning stand to prepare for the next iteration of sizing adjustments. Often, multiple changes can be made at once. It is up to the preference of the engineer on how many changes to make at a time, always keeping in mind the comfort of the subject when going through multiple pressure cycles. It can be beneficial to make one or two changes at a time to verify not imparting negative changes, though sometimes it might be necessary to make multiple. When doing this, always re-

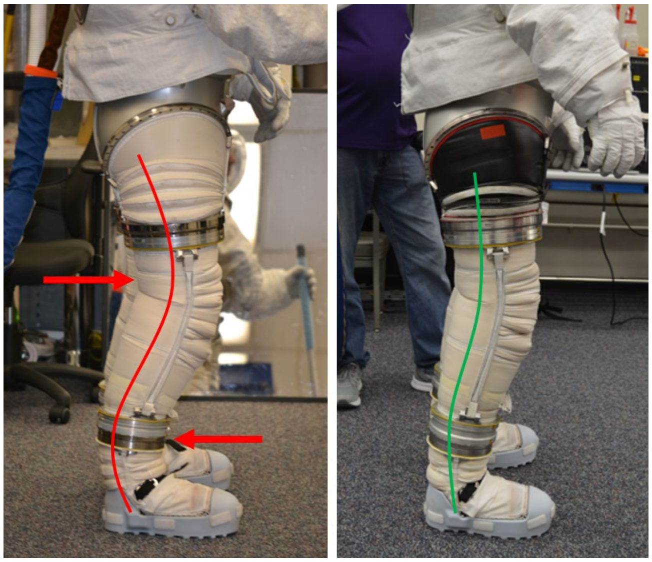

Figure 7. "S" shape effect in legs in 1-G lab.

assess full suit fit as even minor changes in one area could affect fit in another. It is essential to remember that all of the hardware is connected; if length is taken out of the leg, length might need to be added to the waist or shoulder straps to maintain an acceptable shoulder to heel length; this could also impact the shoulder positioning which could impact arm length.

Finally, it is again important to remember that fit in 1-G isn't necessarily indicative of fit and comfort in a planetary environment or in the simulated environments that are currently used for testing. In a standing posture, the suit can self support a majority of it's own weight, but the subject must support the majority of the suit weight when moving through it's range of motion. As mentioned before, offloading the subject in the fitcheck is critical to understanding the subjects' fit in the simulated gravity test environment.

VII. Suit Fit Verification

The end goal of a fitcheck is to establish a functional and comfortable suit fit configuration for the test subject to be able to move into a test evaluation and provide valuable feedback, independent of sizing impacts. However, sizing verification should always be included in the beginning of an evaluation at any new test facility. The interaction between the subject and the suit hardware changes when altering the offload experienced by the suit and subject.

Since these evaluations are performed within Earth's gravity, simulating alternate gravity environments, the offload is applied to the suit hardware, but the subject within the suit will still experience Earth's gravity[4]. Thus the suit is being lifted around the subject and the subject is still falling into the suit. Due to this interaction, one of the more common points of discomfort for subjects in these new environments comes from the change in crotch contact. This can be mitigated with crotch padding, or even lengthening the waist, and/or shortening the legs. All of these experiences are subjective and rely on good communication between the test subject and the suit test engineer for a successful fit and test. Figure 8 shows subjects performing mobility tasks to assess suit fit in different lunar offload test environments.

Figure 8. Subjects performing mobility tasks in different environments to establish acceptable fit. Test facility: ARGOS (left) and NBL (right).

VIII. Conclusion

Achieving an acceptable suit fit configuration for each subject can be a tedious process, often filled with several adjustments, but it can make a tremendous difference in subject performance if performed correctly. The process starts with calculating a baseline configuration, progressing through a fitcheck to establish a functional and comfortable configuration, and concludes with fit veritifcation at every new test facility as the human to suit interaction changes. Each subject will have a different experience with the suit and will have different preferences on how they prefer the suit to fit, showing why the fit process can't be achieved solely with calculations. Having a proper suit fit will lead to successful data collection events, reliable commentary from subjects, and subject ability to continue for longer duration tests.

References

[1] "Sizing and Fitcheck Guide for the xPGS Assembly." Crew and Thermal Systems Library: CTSD-ADV-1859, 2021.

[2] Flaspohler, C., Mcfarland, S., Rhodes, R., "Exploration Extravehicular Mobility Unit (xEMU) Project Test Report for Exploration Pressure Garment Subsystem (xPGS) VA.XPGS.155, Fit, Comfort and Mobility Design Verification Testing (DVT)", CTSD-ADV-2018, 2022.

[3] FEMU-R-005, EMU Sizing Requirements and Constraints, JSC-65011, 2021.

[4] Tejral, Z. and Rhodes, R. "Advanced Space Suit Performance in Lunar Simulation Environments" In: 53rd International Conference on Environmental Systems. 2024