Exploration Brief

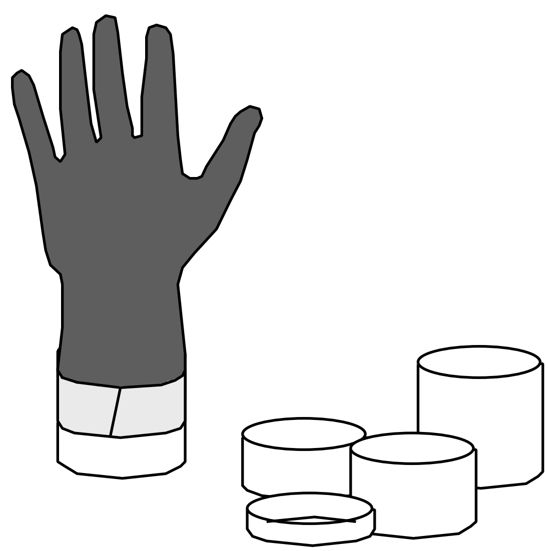
Getting the Right Fit

Context

In spite of many decades of experience in developing and evaluating spacesuits,they are still fatiguing to wear. The internal pressure of the suit creates resistance to movements of the arms, hands,or legs. Consequently, astronauts training for a spacewalk are encouraged to stay in excellent physical condition by training on the ground for endurance and strength. After a spacewalk, crew members are allowed a day of rest before going out again.That is why missions,such as the multi-day servicing of the Hubble Space Telescope, have two EVA crews that alternate spacewalk days.

The exhaustion factor of spacesuits can be mitigated somewhat by insuring that the suit the crew member will wear in space fits properly. It is essential that the position of suit joints precisely match the position of shoulders, elbows, wrists, knuckles, knees, and ankles. A misalignment of a mere centimeter in the arm length, for example, can lead to aching fingers after a several-hours spacewalking.

Getting the right fit is complicated by a number of factors. It is important that the suit fits when it is pressurized. An unpressurized suit is slightly smaller than when it is pressurized. The suit must fit right when the crew member is in space. The microgravity



environment experienced in Earth orbit affects the human body in many ways. One effect is spine lengthening. In one G (gravity), the vertebrae of the spine are close together but are kept separate by rubbery disks that act as shock absorbers. In space, without the perceived directional force of gravity, the disks expand slightly, causing the vertebrae to move slightly farther apart than they are when the crew member is standing upright on Earth. This spine-lengthening causes the astronaut to get taller, resulting in arm joint misalignment. Spine lengthening in microgravity has to be accounted for when astronauts are measured for their suits. The typical astronaut will gain between 2 and 3 centimeters in height while in space.

To avoid the expensive and time-consuming process of creating custom-made suits for astronauts, as NASA did during the Apollo missions, suits with interchangeable parts are used. Different-sized upper and lower torsos are available, but arm and leg lengths are still difficult to match. NASA has solved this problem for the Shuttle EMU by creating sizing inserts that are added or removed from the restraint layer in the arms and legs to achieve the right fit.The inserts are fabric rings of different lengths that are laced into the arms and legs. Selecting the right combination of inserts insures the best fit possible.

Objective

• To experience the measurement process used in sizing a spacesuit arm to fit different wearers.

Materials and Tools Checklist

- ☐ PVC thin-wall sewer pipe (4 in. dia.)
- ☐ Saw (crosscut or hacksaw)
- ☐ Measuring tape or ruler (metric)
- ☐ Duct Tape
- ☐ Vinyl clothes-dryer hose
- ☐ Scissors
- ☐ Thick rubber gloves
- ☐ Sand paper or knife

Procedure

Step 1. *Construct a variety of spacesuit arm segments by sawing off measured lengths of PVC plastic thin wall sewer pipe. (See the tip section for information on where the sewer pipe and other needed materials can be obtained.) Cut the pipe into segments 25, 50, 75, and 100 mm long. Cut two of each size. Cut three additional segments of the 50 mm length.*

Step 2. *Create a suit elbow joint by connecting two of the 50 mm segments with a 25 cm piece of vinyl clothes dryer hose. Slip the hose ends over one end of each ofthe segments.It will be necessary to the hose a small amount to accomplish this task. Fasten the hose to the segments with duct tape.*

Step 3. *Slip the cuff of one ofthe gloves over a 50 mm pipe segment. The fit may be tight but try to slide the ring in so that it just reaches the position of the wrist. Trim off the excess of the cuff so that the glove can be affixed to the ring with duct tape.*

Activity

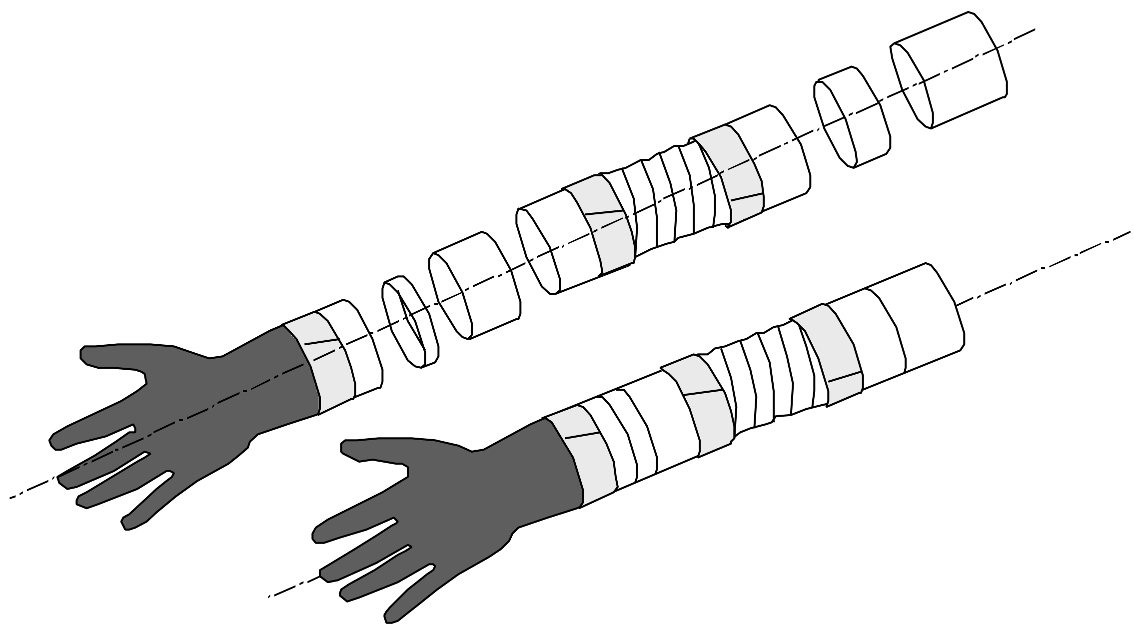
Step 4. *Provide the rings, joint, glove, measuring tape, and duct tape to a group of students. Tell the students to select one member of their group to serve as the astronaut. Their objective is to fit a suit arm to that astronaut.The students should begin by measuring the arm and mapping the range of movement of the arm without the suit. Use the Arm Range of Movement Data Sheet for recording data.*

Step 5. *The students should select the right combination of segments to use to construct the arm. PVC rings are joined with pieces of duct tape.*

Step 6. *After completing the arm, the student group should test it by placing the "astronaut's" arm into the suit arm.They will then evaluate the arm by repeating the range of movement tests done before and by asking the astronaut how comfortable the arm is to wear. If the fit is not comfortable or the range of movements are* *restricted, the student group should adjust the arm length by changing the lengths of the PCV rings used. When the fit is comfortable, and the range of movement is acceptable, record the sizing data in the log chart that is provided. The sizing process can be repeated with a different student.*

Tips

- All the materials for this guide can be obtained at larger hardware stores. Pick a thin wall sewer pipe without holes in its sides. A 10 foot length of pipe is inexpensive and will provide material for several sets of arms.
- A long sleeve shirt worn by the astronaut will reduce any possibility of pinching skin between pipe segments.
- Use the saw to cut the sewer pipe. Have someone help you hold the pipe as you cut it. Use sandpaper or a sharp knife to remove burrs left on the pipe segments after sawing.
- Duct tape pieces can be removed and used again for joining segments. White duct tape can be substituted for gray tape to improve the appearance of the arms or one inch wide masking tape can be used.
- Actual arm measurements for spacesuit fitting involve more measurements than just arm length and range of movement of the extended arm in three planes. Other necessary measurements include upper and forearm circumference, hand and finger size, knuckle location, and movement of the forearm from the elbow.

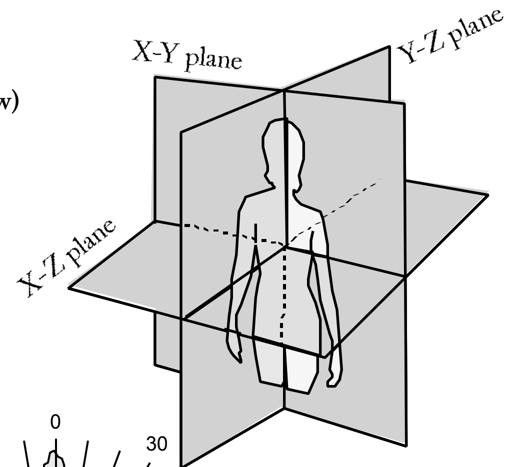


Arm Range of Movement Data Sheet

Subject Name:

Arm Length ___________ cm (shoulder to elbow)

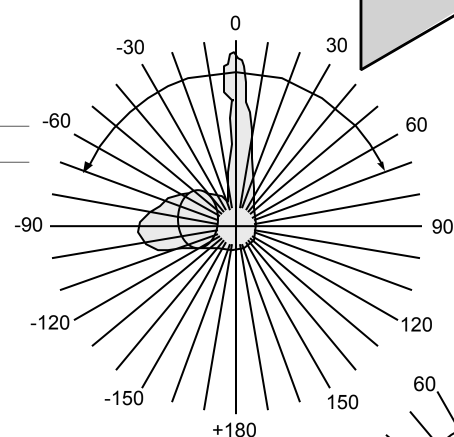
Arm Length ___________ cm (elbow to wrist)



X-Z Plane Movement Range:

0 to + ___________

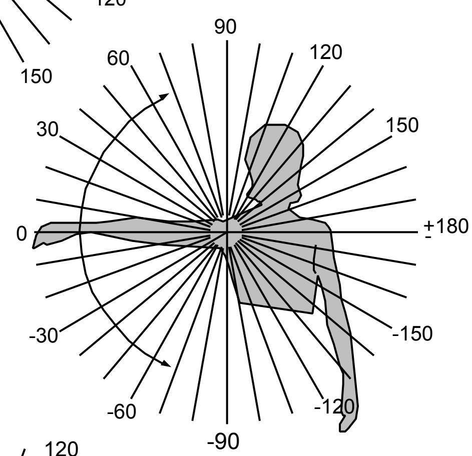
0 to – ___________



X-Y Plane Movement Range:

0 to + ___________

0 to – ___________



Y-Z Plane Movement Range:

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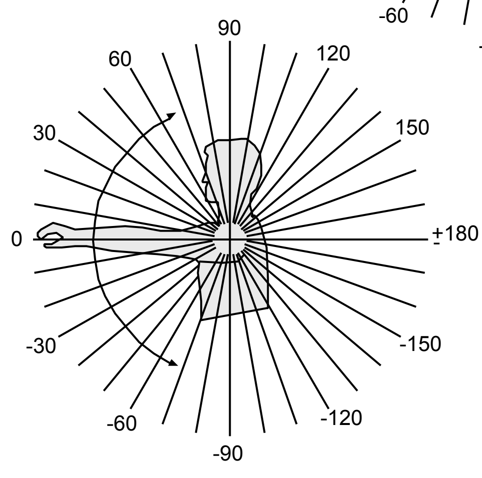
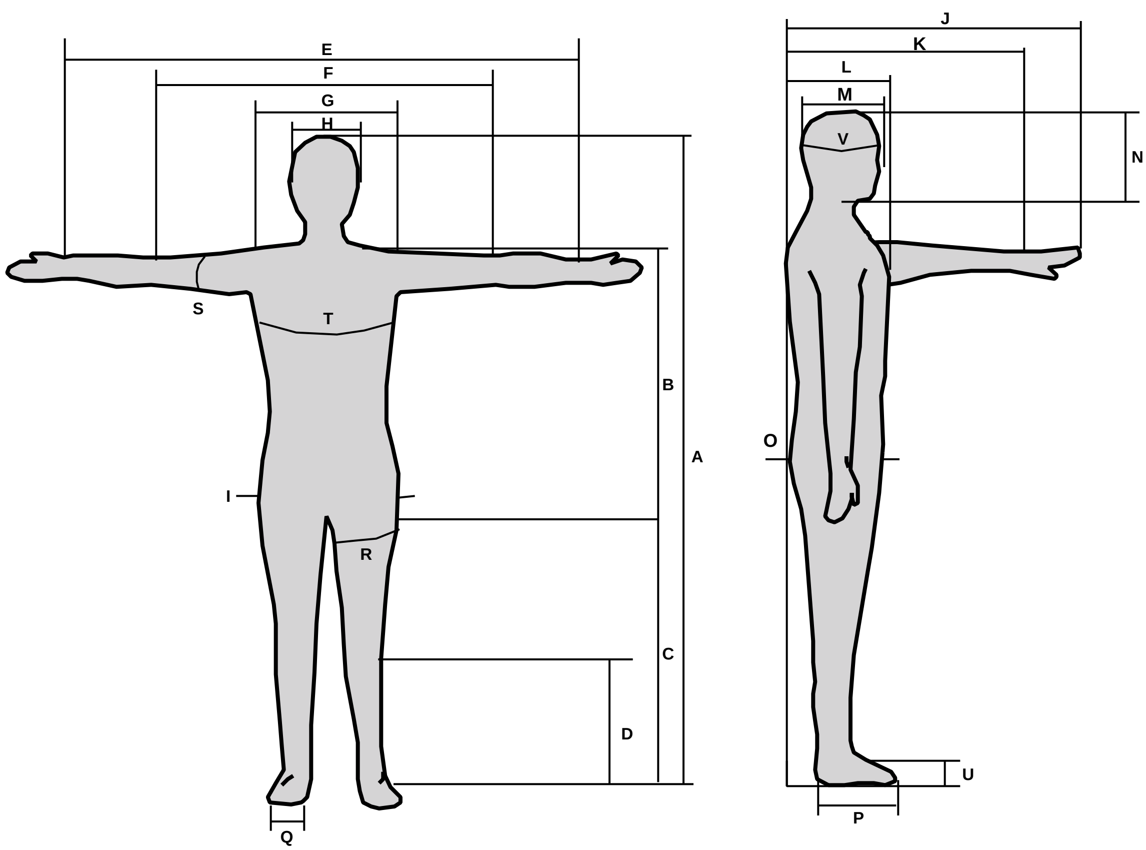
0 to – ___________



Extensions

- When fitting spacesuit components to astronauts, more than 100 measurements are taken. Set up a measuring activity with students and determine the class average for each measurement made. Because of certain sensitivities, you may wish to avoid girth measurements. Refer to the chart on the next page for data covering girth.

  Measurements on the chart provide the range of measurements between the 5th percentile (40-year-old Japanese female) and the 95th percentile (40-year-old American male). These range measurements are projections to the year 2000 in a one-gravity environment.
- Create a computer spreadsheet to compile class data.



Body Size Range Measurements

Based on 1989 Man-Systems Integration Standards, NASA-STD-3000

Category	Minimum (cm)	Maximum (cm)
A. Stature*	162.1	187.7
B. Vertical trunk dimension	64.3	74.4
C. Crotch height	74.4	91.9
D. Knee Height	32.3	38.9
E. Wrist to wrist distance	131.6	167.1
F. Elbow to elbow distance	85.9	106.2
G. Chest breadth	27.9	36.6
H. Head breadth	12.7	16.5
I. Hip breadth	32.3	38.9
J. Arm reach	80.5	94.2
K. Shoulder to wrist reach	62.2	73.7
L. Chest depth	21.3	27.7
M. Head depth	18.3	21.6
N. Chin to top of head	21.8	24.4
O. Hip depth	24.1	29.2
P. Foot length	21.1	27.4
Q. Foot width	8.9	10.7
R. Thigh circumference†	52.1	67.1
S. Biceps circumference (flexed)	27.4	36.8
T. Chest circumference	89.2	109.7
U. Instep	NA	8.3
V. Head circumference	55.5	60.2

* Stature increases approximately 3 percent over the first three to four days in microgravity. Because almost all the change appears in the spinal column, other dimensions such as vertical trunk dimension increase proportionately.

† Thigh circumference will significantly decrease during the first day in orbit due to the shift of fluid to the upper torso.