LTA 19

NASA - AMATYC - NSF
Project Coalition

Kennedy Space Center

NASA Under the Sea:
The Scott Carpenter Space Analog Station

Mathematics for Engineering Technology

Bioengineering
Space

Capital Community College

The Scott Carpenter Space Analog Station (NASA Educational Submersible) at Complex 34.

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NASA Under the Sea: The Scott Carpenter Space Analog Station

Mathematics for
Bioengineering Engineering Technology
Space Engineering Technology

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Jeanne Bowman has taught at the University of Cincinnati since 1980 and has written the student solutions manuals for Applied Calculus and four computer assisted instruction programs.

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For the past 15 years Peg Greene has taught at Florida Community College at Jacksonville. She has co-authored two Intermediate Algebra textbooks and also presents institutes for teachers on the use of technology in mathematics and science.

Dennis Chamberland - NASA Scientist/Engineer
Kennedy Space Center, **Florida**

Dennis Chamberland is the Design Engineer and Principal Investigator for NASA's Scott Carpenter Station. He has a professional and personal interest in Advanced Life Support Systems and has designed several habitats for use in the oceans as an analog for space. One of these habitats, the Scott Carpenter Space Analog Station, was used for two missions in the summer of 1997 and 1998. Dennis was the Mission Commander on both missions, one lasting 11 continuous days while sharing an experiment with the space shuttle in orbit.

Gus Koerner - NASA Scientist/Engineer
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Gus Koerner is a Curriculum Coordinator of NASA's Space Life Sciences Training Program (SLSTP). He is interested in research on crop plants in controlled environments for support of extended space flight missions. His speciality is environmental monitoring and implementation of hydroponic plants in the K-6 classroom.

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NASA Under the Sea:
The Scott Carpenter Space Analog Station

Wait! Isn't NASA the space agency? Well, yes, but part of NASA's mission is to share what it has learned about space travel. Very few of us have ever been in space ourselves, so the Scott Carpenter Space Analog Station was created in order to explain some of the ideas relating to space life support systems. The Station is an example of a habitat that is closely related to living in space. It demonstrates concepts of space life support systems by modeling space missions in an underwater environment. For example, in both environments inhabitants are isolated, and it is necessary to import a breathable atmosphere, food, water, and power. Underwater and space environments also require special systems for regulating and monitoring the environment, protecting occupants from heat and cold, communication, and waste removal. Finally, an underwater environment can be used to simulate weightlessness.

The Scott Carpenter Space Analog Station was created in 1997. It was designed by Dennis Chamberland, Life Sciences Outreach Coordinator at Kennedy Space Center. The Station was named in honor of Scott Carpenter, who is both an astronaut (circling the earth three times on May 24, 1962) and an aquanaut. He was chosen as commander of the underwater Station Sealab II in 1965. His interest in undersea research continued after his retirement from NASA. In 1995 he spoke to astronauts in the Space Shuttle Endeavor from an underwater laboratory off the Florida Keys.

The Scott Carpenter Space Analog Station is one of four functioning underwater habitats in the world. The other three underwater habitats are named Jules, MarineLab, and Aquarius. The Station was originally developed and built as part of Kennedy Space Center's Mission to America's Remarkable Students (MARS). It was designed to travel easily to schools, something that cannot be done with the Shuttle, and it can be launched from an ordinary boat ramp. This makes it very cost efficient to use for demonstrations for schools and the general public. In 1997 and 1998 it was secured to the sea floor off Key Largo, Florida and operated continuously for 31 days. The main purpose was to increase student and public interest in both the sciences and the space program.

The Station is the size of the Apollo Command Module or the size of a family van and weighs approximately 21,000 lbs (10.5 tons). It took about a year to build at a cost of $71,500. It can house up to four people for short periods of time and up to three people for more than 24 hours. Power and air are supplied to the Station from the surface either through a supply pod or directly from shore. The systems needed to operate the Station are also run off 12-volt batteries. There are two converters. One changes 110 volts AC to 12 volts DC and the other one reverses the process.

The Scott Carpenter Station can go to a depth of up to 27 ft due to decompression constraints. It is an ambient pressure habitat, not designed to have a cabin that is maintained at atmospheric pressure. The aquanauts breathe air that is pumped into the top of the cabin in a steady stream.

This in turn pushes air out an open hatch at the bottom of the cabin and keeps the surrounding water from entering the cabin. Therefore, the pressure inside the cabin must be equal to the pressure outside at the hatch.

Aquanauts come and go through the open hatch in the bottom of the cabin. Every day food is brought into the cabin and garbage and anything else they are sending to the surface is removed through the hatch in 50-pound containers. Since air is continually bubbling out through the hatch, this also provides an opening for the excess carbon dioxide, CO_2, produced by the aquanauts' breathing to escape from the cabin before the concentration builds to toxic levels. One breath of air taken in has 0.04% CO_2 and one breath exhaled has 4% CO_2. At these rates the amount of CO_2 in the cabin could quickly reach critical levels unless it is removed.

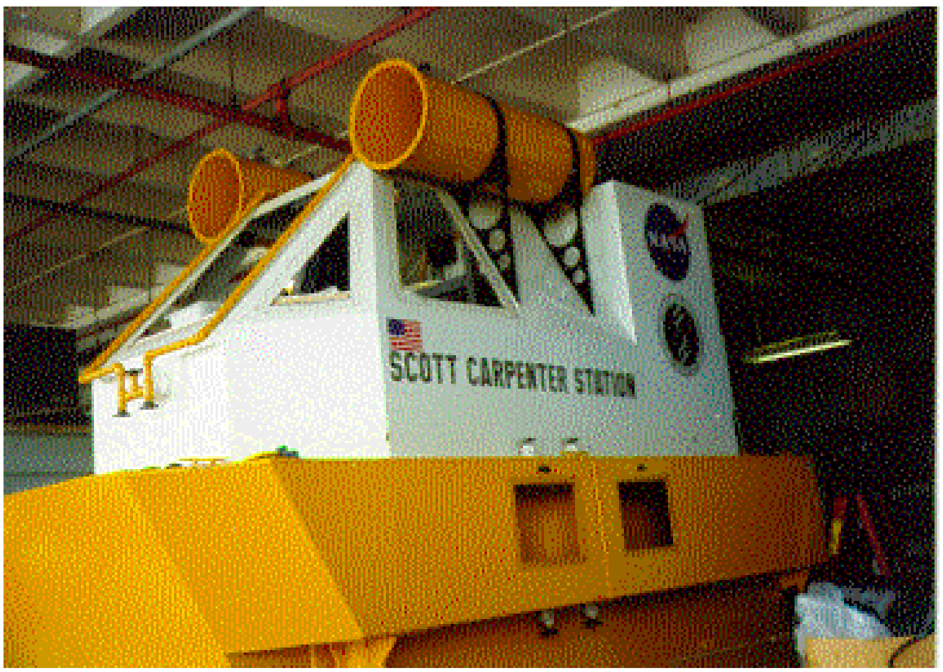


Figure 1 - Scott Carpenter Space Analog Station

In designing and building the Station the engineers faced many challenges. One of these is the effect of the underwater pressure on the Station. This is the application that we will consider.

The pressure of the atmosphere around us is relatively constant at sea level. However the pressure changes as we increase our depth in sea water. The pressure at sea level is 1 atmosphere and increases by one atmosphere for every 33 ft increase in the depth of the water. One atmosphere is equal to 14.7 pounds per square inch (psi).

Consider the sketch in Figure 2 as you answer the following questions.

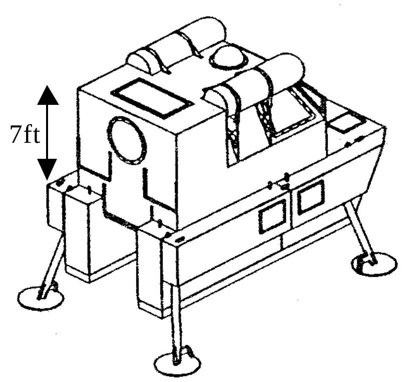


Figure 2 - Schematic of Space Analog Station

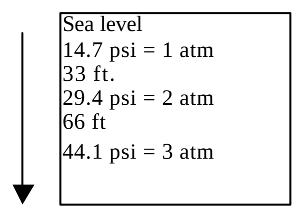
1) What is the change in pressure in psi as you increase the depth by 1 ft intervals? Assume a linear relationship.

2) Write a sentence stating the relationship between the depth in feet and total pressure in psi.

3) Complete the following table and then use the information from the table to find a function P(X) giving the pressure in psi with respect to X feet of depth.

Table 1

Depth in ft.	Pressure in psi
1	
2	
3	
4	
: :	
33	
X	



P(X) = ______________________________

4) Sketch the graph of your function.

5) What is the slope of your function? What does it mean in this situation?

6) What is the y-intercept of your function? What does it mean in this situation?

Next, let's consider the difference in pressure at various points inside and outside the Station.

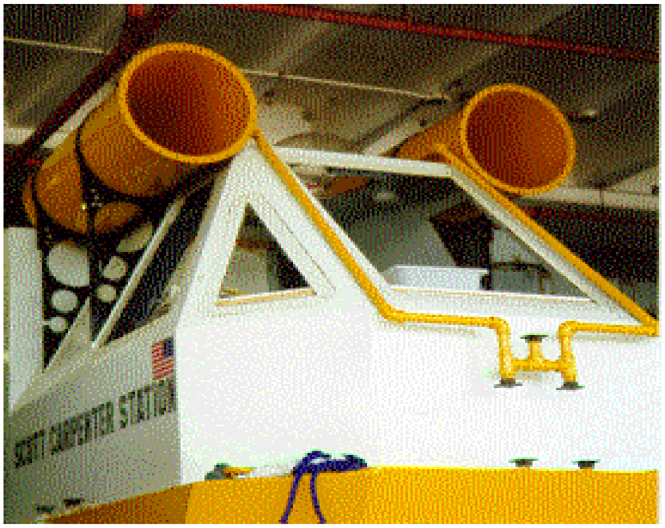


Figure 3 - Scott Carpenter Analog Space Analog Station

7) In order for the hatch to remain open at all times the pressure everywhere inside the Station must be equal to the pressure of the water at the hatch. What is the pressure of the water at the hatch if the hatch is at 21 ft below sea level?

8) If the height of the cabin is 7 ft, what is the difference in pressure in the water outside the cabin between the level of the bottom of the cabin by the hatch and the level of the top of the cabin?

Suppose the bottom of a vertical window on the station is 3 ft from the bottom of the cabin, and the top of this window is 1.5 ft from the top of the cabin.

9) Find the difference in the outside pressure between the top and the bottom of the window. (Recall that the cabin is 7 ft high.) Why is this significant to the engineer who is designing the window? How does it affect the thickness of the glass? How does it affect the strength of the bolts securing the window to the frame in various places?

10) Use your answers from Exercises 7-9 to complete Table 2.

Table 2

Location	Depth in feet	Pressure outside the cabin at this depth	Pressure inside the cabin at this depth
Top of cabin			
Top of window			
Bottom of window			
Hatch (bottom of cabin)			

11) Is the pressure of the air in the cabin greater or less than the pressure of the water outside the cabin?

Every day a container of food is brought down from the surface. The container looks like a briefcase with rounded corners and two catches. It is 18 inches long, 12 inches wide, and 4 inches deep. This case is filled with food (such as frozen microwave dinners) on the surface and brought down to the opening at the bottom of the cabin. As it is lowered, the pressure that the case experiences changes and the sides of the container are pushed in. By the time the case reaches the aquanauts inside the cabin, the difference in pressure is so great that they cannot open it without equalizing the pressure by means of valves built into the case. When the valves are opened the container returns to its original shape.

12) What change in pressure (in psi) is needed so that the pressure inside the case is equal to the pressure outside the case (inside the cabin of the Station)?

After the aquanauts take out and store the food, they can fill the container with items they want to remove from the cabin, and return the case to the surface. The case is designed to minimize leakage as it passes through the water, but the aquanauts wrap important items in plastic before sending them up, just to be sure.

13) As the case is returned to the surface, what happens to the case? (Recall that as it was lowered to the Station, the sides of the container were pushed in.)

As the case moves upwards the case “burps” the way plastic food containers do, in order to equalize the pressure.