PREDICTING METABOLIC RATES OF ASTRONAUTS

Background

The Biostatistics Laboratory (BSL) is one of several research laboratories which support ongoing biomedical research in human spaceflight conducted by NASA's Human Research Program. Lab personnel often aid in the preparation of research proposals that describe the experimental design, statistical modeling, and analysis of anticipated research data. Once data is gathered, statisticians also assist with the analysis and interpretation of the results.

One area of spaceflight in which the BSL has provided consulting is with the health concerns associated with Extravehicular Activities (EVA), or spacewalks. Results of the research analysis in this area helps engineers design better spacesuits for future explorers.

There are a number of factors associated with life support that are considered when designing a spacesuit. Statisticians help to collect and analyze data about the different factors involved and how each one affects the astronaut's performance, comfort, and health during an EVA.

The spacesuit currently worn by astronauts performing an EVA is called an Extravehicular Mobility Unit (EMU). Fully equipped, an EMU becomes an astronaut's "one-person spacecraft". It must protect astronauts from multiple conditions that can be experienced in space. The EMU shields them from extreme temperature changes, and protects them from being injured from impacts of small bits of space dust and from radiation. It contains a life support system that supplies astronauts with breathable oxygen, removes exhaled carbon dioxide, and provides drinking water—enough resources for an eight and a half hour EVA. The EMU also supplies electricity to a number of other systems, including a Liquid Cooled Garment (LCG), which covers the entire body, except for the head, hands, and feet. During an EVA, adjustable amounts of cool water are pumped through the tubes (which are woven into the LCG) to keep each astronaut at his or her own temperature comfort level.

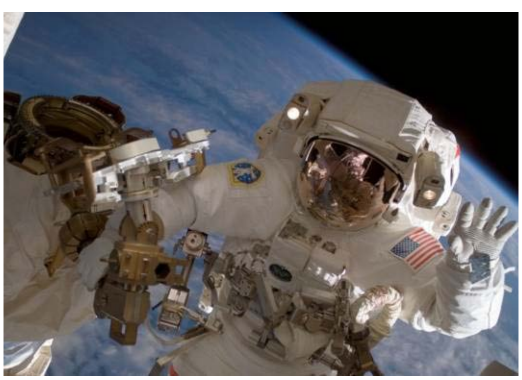

Figure 1: An astronaut during an EVA on the International Space Station

Figure 2: An artist depiction of astronauts exploring the lunar surface

As NASA prepares to explore new frontiers of space, the capabilities of the spacesuit used must be carefully considered. Human exploration in the next few decades could include more extensive exploration of the Moon, visits to near-Earth objects (like asteroids), and the exploration of Mars. These environments have different variables that would each contribute to the best design of a spacesuit. By designing models that factor in these variables, the work of statisticians continues to be an important step in NASA's goals for future exploration.

Problem

On the TI-Nspire™ handheld, open the document, *Metabolic_Rates*, read through the problem set-up, and complete the instructions and questions embedded within the document.

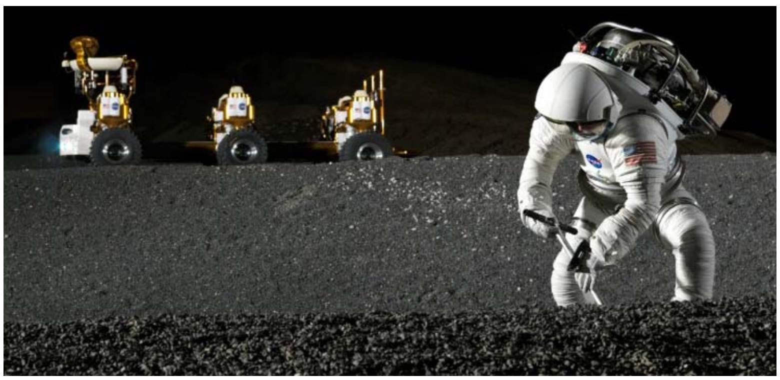

Figure 3: A spacesuit engineer simulates lunar work in a crater of NASA Johnson Space Center's Lunar Yard

A. Use the scatter plot on page 1.9 of the TI-Nspire document to determine which pair of the four variables (*LCG*, CO_2, O_2, or *HR*) seems to have the strongest correlation, and which pair has the weakest correlation. (Change the variables by clicking on the labels at the bottom and left side of the plot.)

B. The goal is to produce an estimated metabolic rate using all four different variables. A weighted average is a reasonable approach, but how might the weights be determined?

   Page 1.12 shows time plots for each of the four variables and arrows that can be used to adjust the weight factors. Currently the weights are all set at 0. Change the weight factor of LCG to 1 and leave the others at 0. You will see a graph that goes through all of the points on the LCG time plot.

   See if you can change the weight factors of the variables to result in the graph going through all of the points on the CO_2 scatter plot.

   Now do the same thing for the O_2, and then for the HR scatter plots.

1.13 Go back to page 1.12 and adjust the weight factors so the graph uses all the variables to predict metabolic rate. Not all factors need be equal. If there are some variables you think should have more affect on the prediction of metabolic rate you can give them a greater weight. After you adjust the weight factors, record the selections and explain your reasoning.

LCG weight factor: _________ **O_2 weight factor:** _________

CO_2 weight factor: _________ **HR weight factor:** _________

Explanation for chosen weight factors:

1.14 Page 1.15 shows your estimates of metabolic rate in black along with a graph of NASA's estimates in red. Is your graph close to the NASA graph? Look at your classmate's graph. Who has the closest fit to the NASA graph? What is a good numerical way to determine the closest fit?

C. Page 1.17 shows the estimates you created with your weighted average in the first column and the estimates created by NASA in the second column. Find the sum of the squares of the differences between the two columns. What is your sum? Who has the lowest sum in your class? What does this mean? Why would you square the differences between the estimates?