

# *LTA 13*

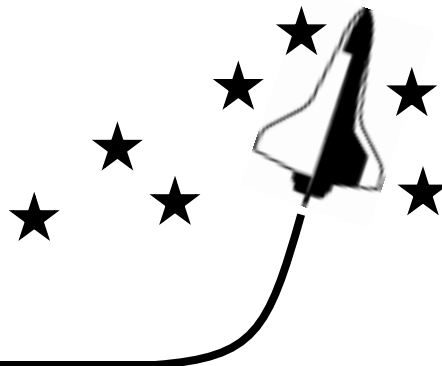
## *NASA - AMATYC - NSF Project Coalition*

*Kennedy Space Center*

**It Ain't Heavy, It's my Crawler**

*Mathematics for Engineering Technology*

**Civil**



*Capital Community College*



The Space Shuttle Discovery and Crawler makes the 3.4 mile journey from the Vertical Assembly Building to Launch Pad 39A.

# *LTA 13*

## **It Ain't Heavy, It's my Crawler**

### *Mathematics for Civil Engineering Technology*

**Julie Hess** - AMATYC Writing Team Member

Grand Rapids Community College, Grand Rapids, **Michigan**

Julie Hess taught at Montcalm Community College from 1994 to 1997 and is currently a faculty member at Grand Rapids Community College, Michigan. She has degrees in Operations Research and Math/Physics Education. Julie was a Founding Officer of Ohio State University's Council of Teachers of Mathematics and was selected to attend the Ohio State University Technology Strategies Workshop sponsored by the National Science Foundation.

**Paul Hess** - AMATYC Writing Team Member

Grand Rapids Community College, Grand Rapids, **Michigan**

Since 1993, Paul Hess has been a faculty member at Grand Rapids Community College. He served as a panelist for curriculum reform at a MichMATYC Conference and was elected a NISOD Medallion winner by fellow faculty members. Paul has been involved with numerous math solving problem competitions, has done extensive work with the TI-92™ calculator, and has received a grant to purchase calculators for his college.

**Krista Shaffer** - NASA Scientist/Engineer

Kennedy Space Center, **Florida**

Krista Shaffer is employed as a construction project manager and has managed numerous and varied types of field related issues on multiple projects without adversely effecting project schedule. She was a Project Engineer responsible for overall performance measurement and management of all industrial engineering aspects governing the new Joint Base Operations Contracts for KSC, Cape Canaveral Air Station, and Patrick Air Force Base. Krista successfully handled a complex engineering investigation and design for the crawlerway tunnel, resulting in a recommendation from NASA Senior Management.

#### Project Grant Team

**John S. Pazdar**

Project Director

Capital Community College

Hartford, Connecticut

**Patricia L. Hirschy**

Principal Investigator

Asnuntuck Community College

Enfield, Connecticut

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**Peter A. Wursthorn**

Principal Investigator

Capital Community College

Hartford, Connecticut

## LTA 13

### It Ain't Heavy, It's My Crawler

You may have seen the Space Shuttle out on the launch pad ready to take off. It is an impressive sight, a vehicle weighing more than 4 million pounds (mostly from the fuel needed to lift off) ready to be blasted into space. What you may not know is how it got there. A special vehicle called a Crawler takes the Shuttle to the launch pad at the whopping speed of 1 miles per hour. NASA had to build a special road to get the Space Shuttle from the Vehicle Assembly Building, where fuel tanks are attached to the Orbiter, to the launch pad. Why? The weight of the Shuttle, the Crawler, and the mobile launch platform (MLP), all together over 17 million pounds, would crush a normal road. This special road called the Crawlerway consists of two lanes that are each 40 feet wide. The lanes are separated by a 50-foot median. The Crawlerway has four layers that support the huge weight. The top layer is from 4 to 8 inches of gravel. Below that is 3 feet of graded and crushed stone, then 2.5 feet of hydraulic fill, and finally 1 foot of selected fill. If you would like to see pictures of the Crawler and Crawlerway, go to the following web sites:

<http://www.ksc.nasa.gov/facilities/crawler.html> or  
<http://www.ksc.nasa.gov/facilities/crawlerway.html>.

Krista Shaffer is an engineer at NASA's Kennedy Space Center in Florida. She has worked in the Construction Management office and currently works in the Joint Project Management office. You have been hired as her summer intern and are going to help her solve a critical problem that has been discovered by workers in the Maintenance and Operations office. There is a tunnel containing utility lines (gas, electric, etc.) that cuts underneath the Crawlerway at one point. This tunnel is used to get the necessary utilities to the launch pads. While inspecting the gas lines, workers from the Maintenance and Operations office noticed cracks in the concrete walls of the tunnel. As you might imagine, if this tunnel were to collapse there could be serious repercussions. The Space Shuttle is made up of numerous delicate instruments. If the tunnel were to collapse while the Shuttle was going over it, the Crawler and the Space Shuttle could be significantly damaged. The cost could easily run into millions of dollars. As reported by the engineering firm that was hired to look into the problem, "Since the failure of the existing tunnel ... could produce unacceptable damages to the crawler-transporter, the MLP and/or the Space Shuttle, the structural safety of the tunnel is of vital importance." [Project Documentation, March 1994, RS&H]

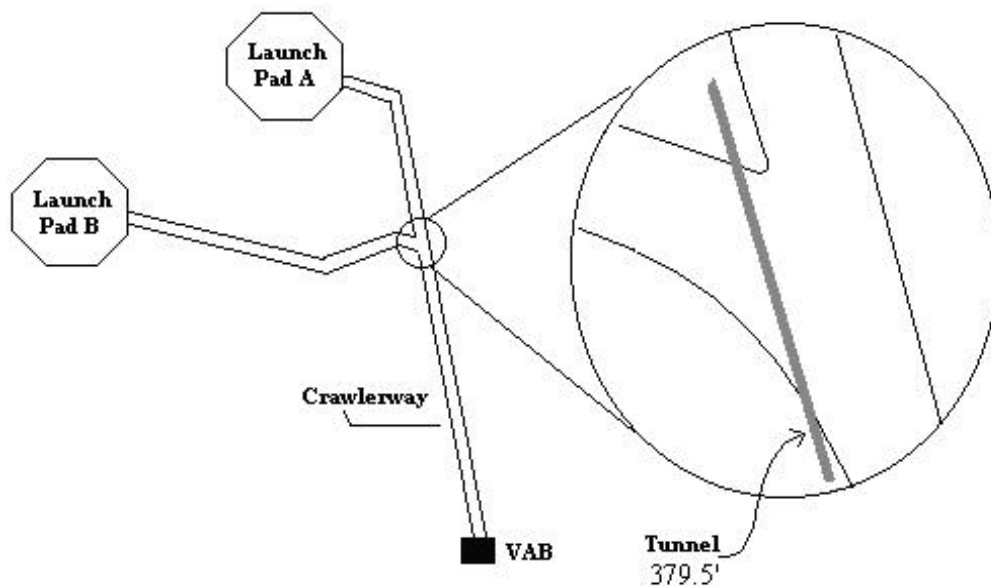


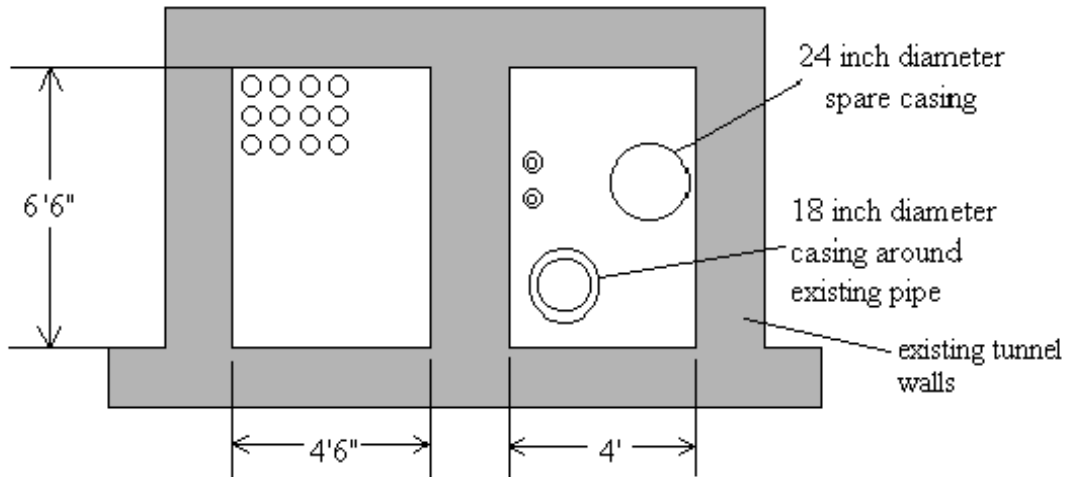
Figure 1

The engineering firm RS&H along with the NASA engineers have considered several possible solutions. The decision has been made to completely fill in the tunnel with a cement-like mixture called Flowable Fill. This decision was made to keep costs as low as possible. It is estimated that this option would cost approximately \$700,000 compared to the 1 million or more dollars for the other options. However, there is one serious drawback. Can you guess what it is before we tell you? Remember how the cracks were discovered in the first place. Inspectors were checking out the gas lines. The last time we checked, inspectors had a little bit of trouble moving through solid concrete. Therefore, part of this solution involves making sure that we can still repair the pipes and wires or add new ones later if necessary.

O.K. Now you have a basic understanding of the problem. Let's help Krista solve it! Using the mathematics you already know, you will be able to help a NASA engineer solve her problem! Good luck. Everyone is counting on you.

### How much do we need?

Figure 2 shows a cross-sectional view as you look into the end of the tunnel. (Recall from Figure 1 that the length of the tunnel to be filled with Flowable Fill is 379.5 ft.) The tunnel actually consists of two parts separated by a wall which you could think of as two tunnels. There were three pipes running through the right side of the tunnel. Krista and her colleagues decided to put a casing (a larger pipe) around each existing pipe to make it possible for them to be removed later if necessary. Also, an additional 24 inch casing was to be placed in the right tunnel so that a new pipe could be added in the future if necessary. The left tunnel had some trays holding cables. These trays were removed and replaced with a duct bank (bank of pipes) at the top left of the tunnel to house the cables. The engineers from the maintenance office were not too thrilled about the idea of not being able to get to the pipes anymore. In order to reduce the maintenance needed on the pipes, Krista's office agreed to have electrical charges applied to the pipes to help keep them from rusting.



**Figure 2**

Note: Each of the fourteen small pipes has a diameter of 4 inches. The two on the right currently have cable running through them.

3) Describe the steps you will follow to calculate the amount of Flowable Fill needed to fill in the empty space in the tunnel.

2) Carry out the steps you outlined in Exercise 1 to determine the volume of Flowable Fill needed to fill in the empty space in the tunnel.



- 6) Assume that all of the Flowable Fill from the 71 truckloads settles to the bottom so that an air pocket is at the top. Also assume that the fill is divided between the two sides of the tunnel in such a way that the height of fill in each tunnel is the same. Approximate the amount of space left empty at the top of the tunnel. Would there be enough space for a rat to run through, a person to crawl through, ...? Justify your answer.

### **Epilogue:**

In the NASA tunnel problem, Krista and her colleagues also determined that the tunnel was not completely filled. They had to convince the contractor that he had not completed his job. He insisted that he had done the job completely because the Flowable Fill was starting to come out of the tunnel. Because Krista had carefully calculated the needed fill and kept track of how much was put in, she knew they needed to look into the discrepancy. When holes were drilled in the top of the tunnel, it was determined that air pockets had formed, probably because the contractor had not put in enough vents to allow the trapped air to escape. See, if you don't know your mathematics, you can end up in deep trouble. Imagine if Krista had spent \$700,000 of taxpayer money, the tunnel cracked anyway, and a multi-million dollar Space Shuttle was ruined!