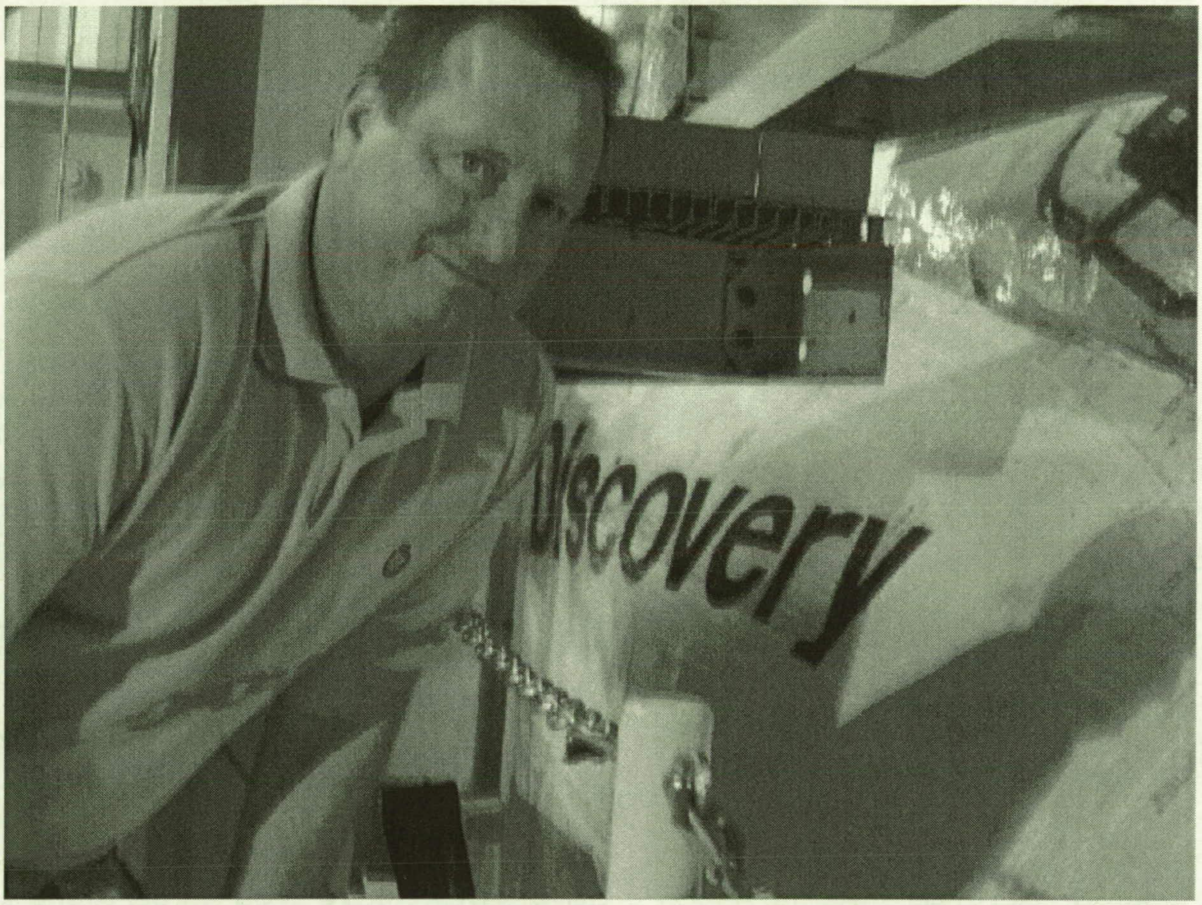
Teacher's Action Plan for

"Shuttle ET & SRB Math"

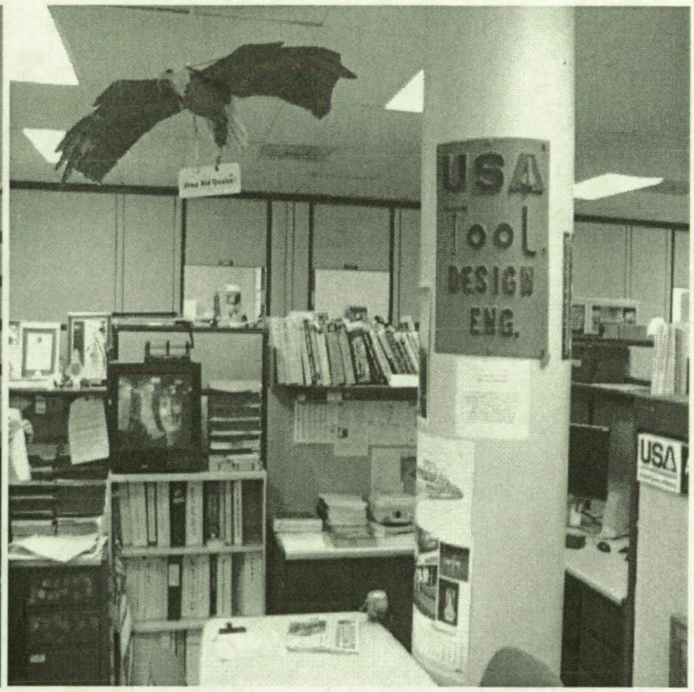
By Mike Prince

Introduction



My name is Mike Prince and I was one of eleven Brevard County teachers selected by United Space Alliance, LLC (USA), to work at the Kennedy Space Center (KSC) along side USA & NASA engineers during the Summer of 2007.

Operations Support Building (OSB I)



OSB I ***USA Tool Design***

I worked on the 4th Floor of the Operations Support Building (OSB I) in the USA External Tank (ET) and Tool Design Engineering Department.

USA Tool Design

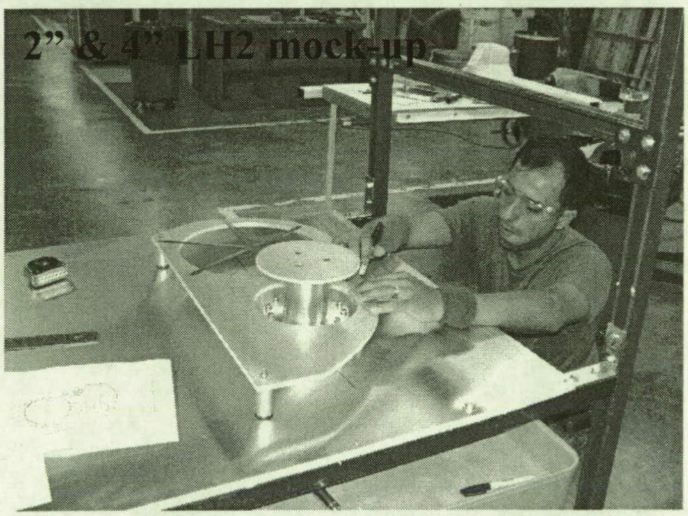

Quick disconnect line holder

Step stool

Design engineers in my department planned, developed, and fabricated tools & shop aids (SA's) for use on the STS (Shuttle Transport System). Since I was leaning toward using my SIFT experience to enhance my Geometry book's unit on "Surface Area & Volume", I chose not to have my students design shop aids.

ThermoForm Lab


2" & 4" LH2 mock-up


2" & 4" LH2 mock-up


Canadian Arm protective covers

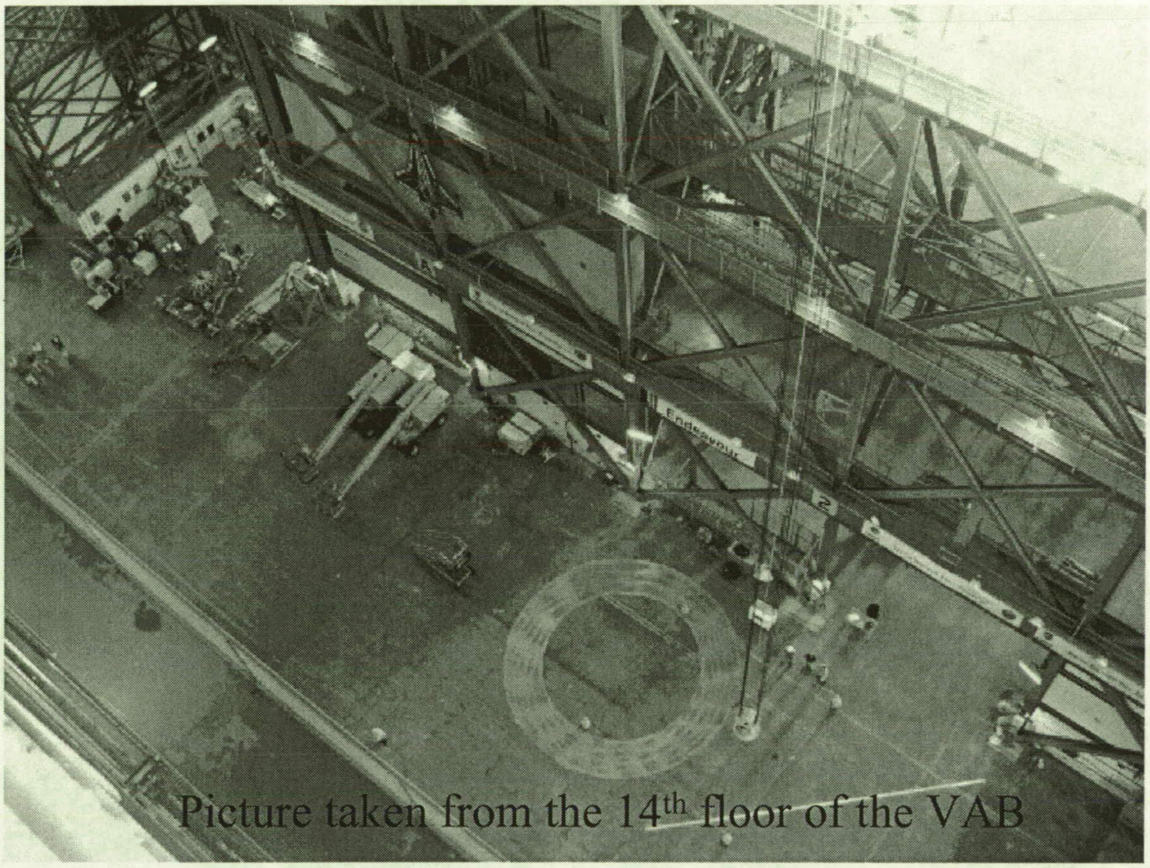
Tool design engineers not only create tools & shop aids, but they also design mock-ups of Shuttle / ET / SRB equipment. I briefly considered having students design & construct mock-ups of the Shuttle, or any of its components, but this project might have proven too difficult for many students who had limited drafting and drawing skills.

Vehicle Assembly Building (VAB)

Notice the hurricane damage between flag & logo.

The solution to my dilemma was found inside the VAB, the 525 feet tall (52.5 stories) building where engineers and technicians work on mating the orbiter, the external tank, and the solid rocket boosters. Each star on the building's American flag is 6 feet tall !

Vehicle Assembly Building (VAB)



Picture taken from the 14th floor of the VAB

No one truly appreciates the size of the VAB until you actually venture inside this massive structure. The Shuttle and its rocket boosters must be ENORMOUS if it takes a building of this size and magnitude to house them.

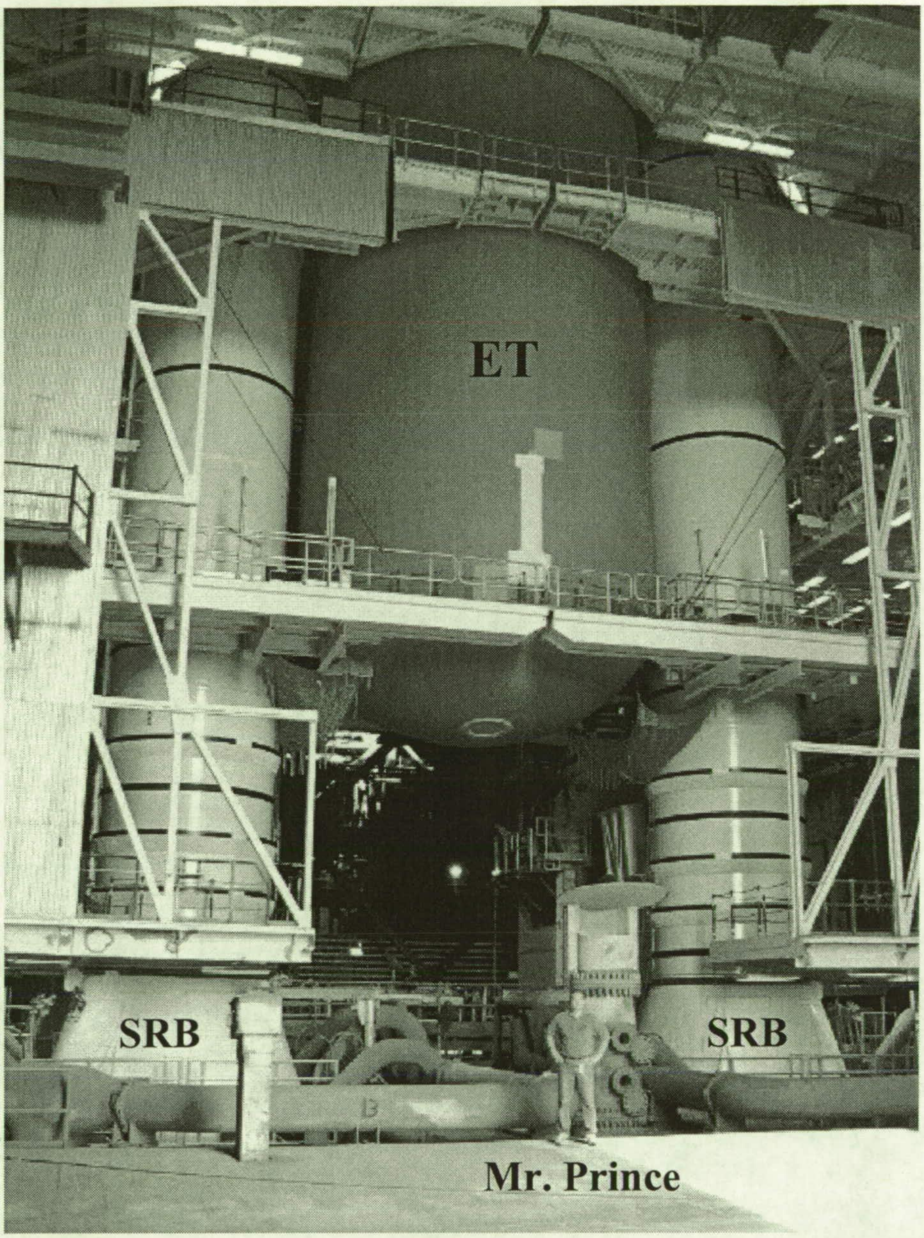
View from the 16th Floor

Vehicle Assembly Building (VAB)

The VAB was originally built for the assembly of Apollo/Saturn vehicles and was later modified to support Shuttle operations. High Bays 1 & 3 are used for the integrating and stacking of the complete Space Shuttle vehicle. It was here that I came up with a GREAT idea!

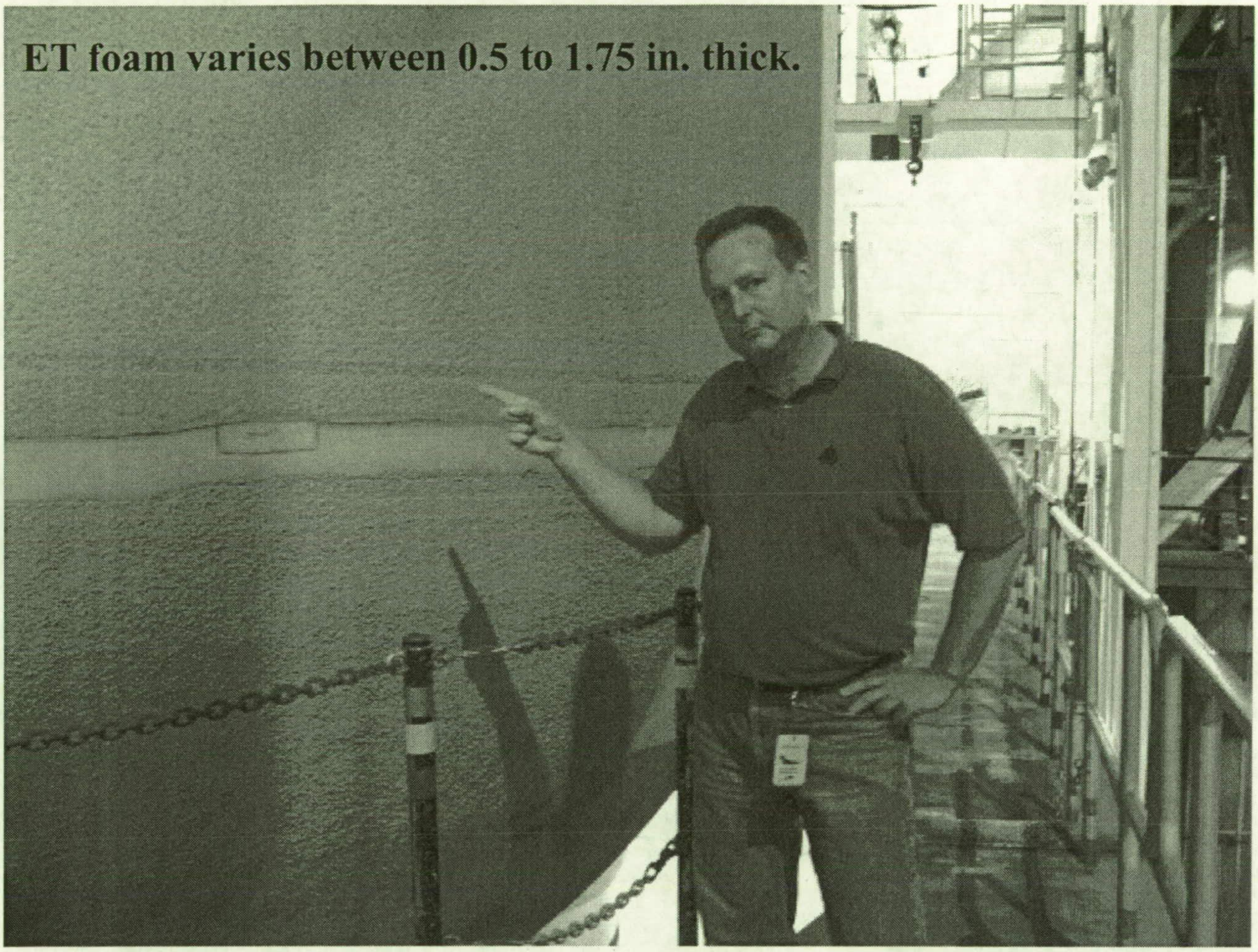
The ET & SRB's in High Bay 1

Vehicle Assembly Building (VAB)



While in High Bay 1, I came up with an easy (and very geometric) unit of study that I could use with students from 7th thru 10th grade: they would first make scale drawings of the ET & SRB, and then figure out the surface areas and volumes of both.

The External Tank (ET)

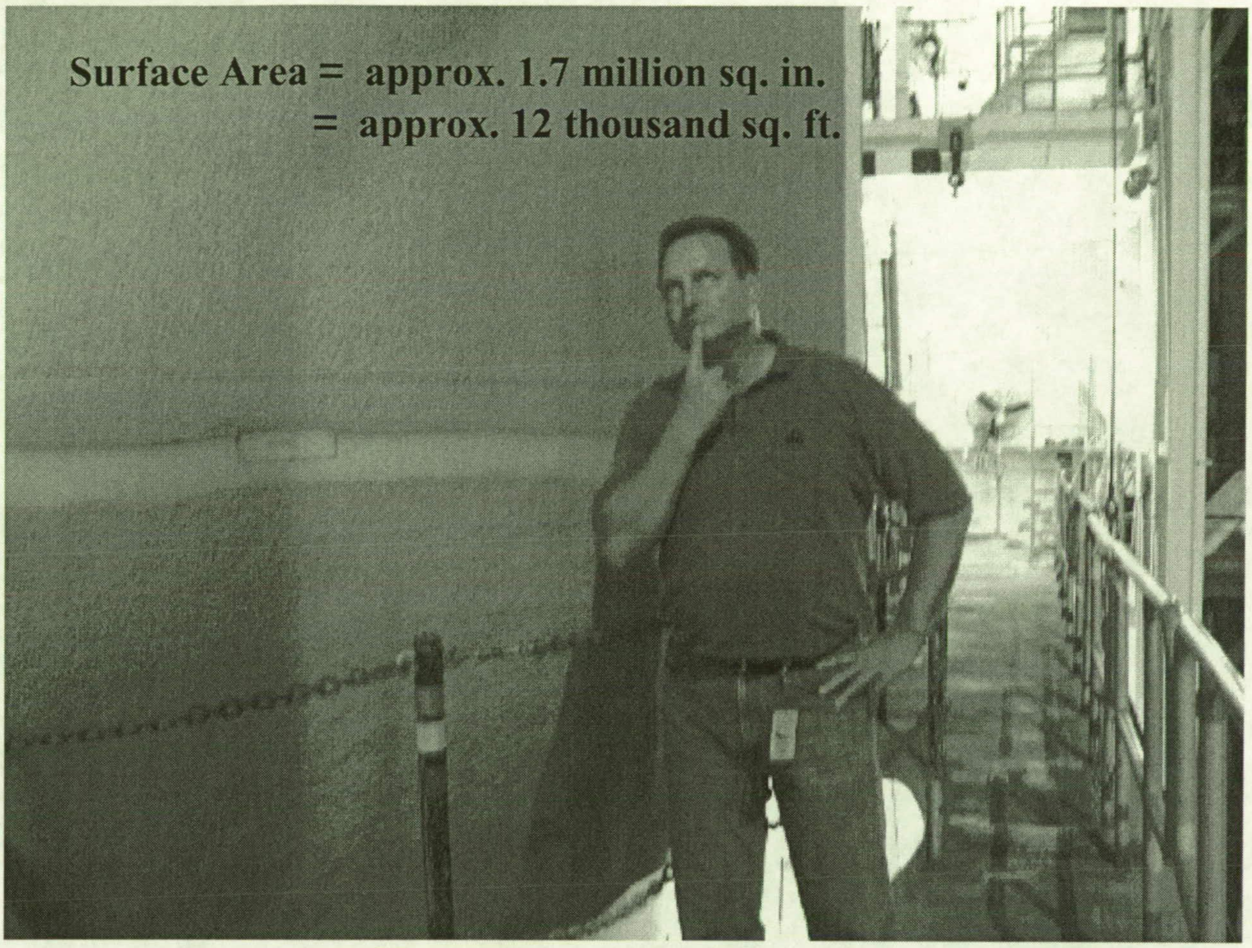


This is the Shuttle's external tank that houses the liquid hydrogen (LH2) fuel and the liquid oxygen (LO2) oxidizer. Rather than confuse my students by having them find the volumes of all 3 tanks, I chose to have them concentrate on only the outer tank's volume and surface area.

The External Tank (ET)

How much volume does the ET have? That is just one of the many questions my students will have to answer.

The External Tank (ET)

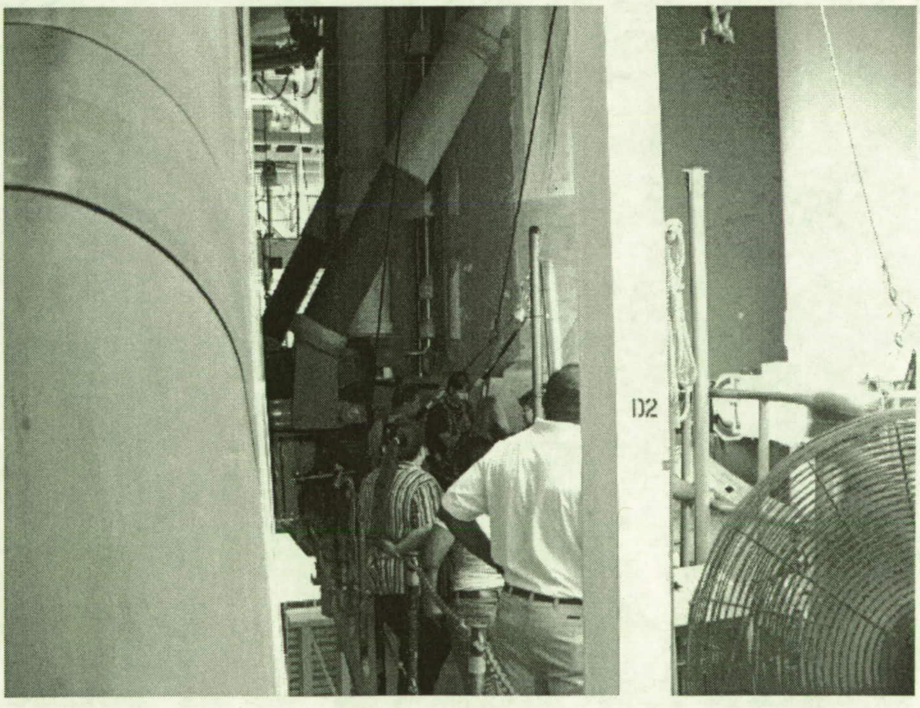


And I wonder how much it costs to coat the outside of the tank with this lovely orange thermal foam? (It actually starts out a light yellow color – the UV rays from the sun cause the foam to turn orange). Or, if you know the total price, how can you find out the cost per cubic inch or cubic foot?

The Shuttle & ET

Endeavour in HB 1, July 3, 2007

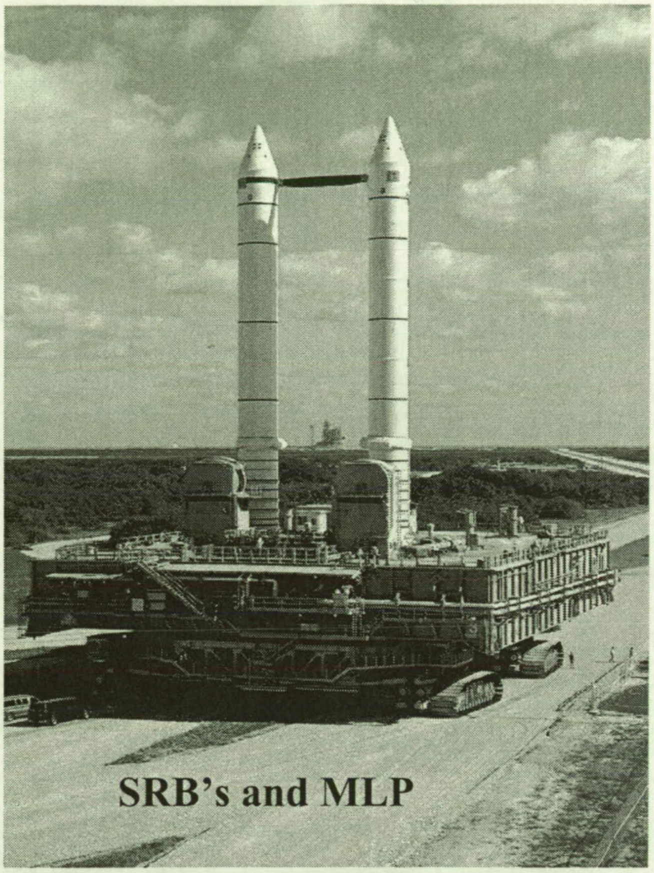
Endeavour was lifted from the center of the VAB to High Bay 1. Pictured at left is its starboard (right) wing. Around the corner…



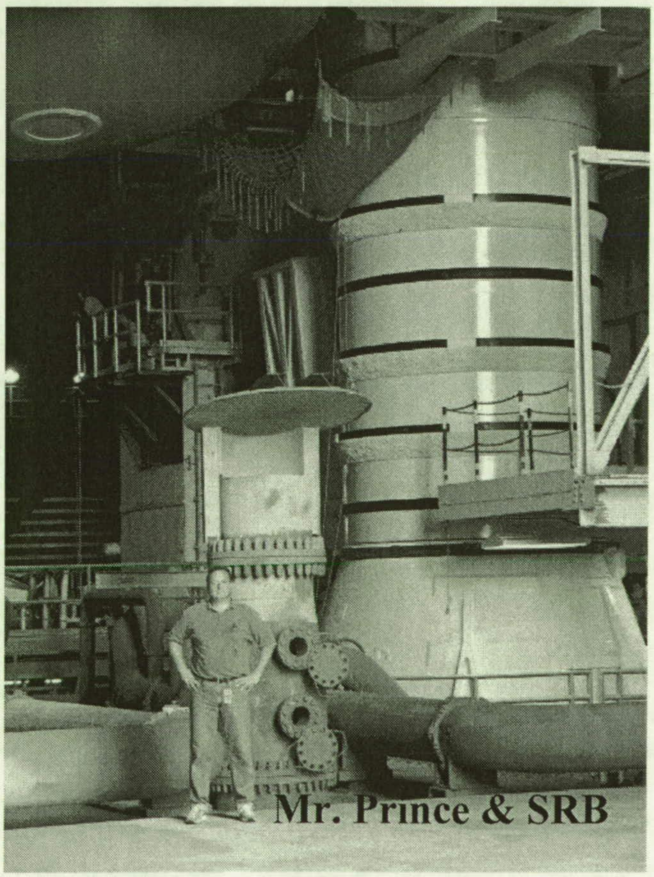
Endeavour, ET, & SRB's – July 3, 2007

… the external tank (ET) and solid rocket boosters (SRB's) are being hard-mated (bolted) to the orbiter.

The Solid Rocket Booster (SRB)


SRB's and MLP

The SRB's are being tested for stability on their way to the VAB while riding on a mobile launch platform. This picture does not give a good perspective of just how large these rockets really are.


Mr. Prince & SRB

This picture shows the enormity of the SRB's (Mr. Prince is 6 ft. 1 in. tall). I wonder how much propellant it would take to fill up one of these rockets? Hmmmm . . . . ! ! !

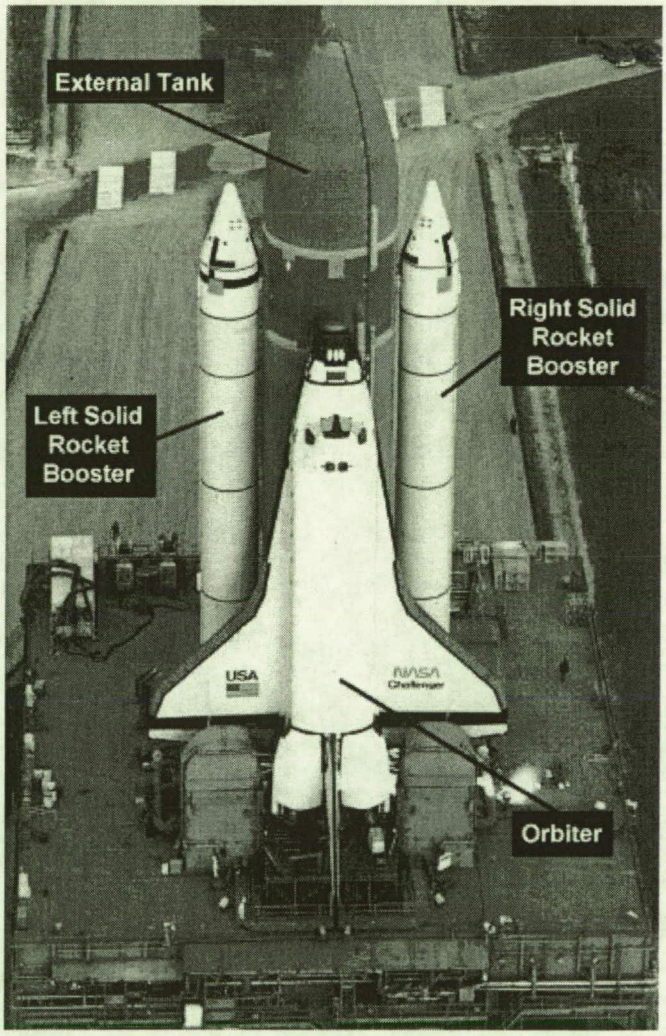
In Conclusion

Here ends the journey of how I used my summer experiences at USA & KSC to come up with an Action Plan and Unit of Study for my students. What follows are the complete lesson plans, student worksheets, and evaluation tools for what I call, “Shuttle ET & SRB Math.” Enjoy !

Teacher's Action Plan for

"Shuttle ET & SRB Math"

USA Instructional Curriculum
Mathematics: Grades 7 - 10
SIFT – Summer 2007
Michael J. Prince
Cocoa Beach High School



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Introduction:

This Action Plan consists of three study levels that build upon one another using two of the components that I worked on during my SIFT Fellowship: the Shuttle Transportation System's External Tank (ET), and its Solid Rocket Boosters (SRB's). All levels of instruction will utilize **ratio, proportion,** and **scale drawings** in order to offer students a deeper understanding of the size and magnitude of the propulsion systems utilized on the STS. Higher levels of instruction also have students calculate the **volumes** of the ET and one of the SRB's, and will have students calculate the **surface area** and cost of spraying foam on the ET.

Shuttle ET & SRB Math Work Levels

Depending on mathematical competency of the students, this Action Plan can be utilized with students from Grades 7 - 10.

The three levels (A, B, & C) begin with **Level A**, which involves the concepts of ratio, proportion, and scale drawings.

The second level (**Level B**) includes all of Level A ***plus*** the concept of volume, and has students calculate volumes for two different shuttle components: the External Tank (ET) and the Solid Rocket Booster (SRB). Formulas for calculating volumes of cylinders, cones, and hemispheres are provided for students, but teachers may delete the formulas to make Levels B & C more challenging for their students.

The third level (**Level C**) includes Levels A & B ***plus*** the concept of surface area, and has students find both the surface area of the ET and the costs per cubic inch and per cubic foot of covering the tank with protective thermal foam. Formulas for calculating surface area of cylinders, cones, and hemispheres are also provided for students, but can be withheld to create a greater challenge.

Guiding Questions:

1. How can you determine what **scale** to use in a scale drawing? (Levels A - C)
2. How can you determine the **volume** of objects that are complex solids or polyhedral composites? (Levels B & C)
3. How can you determine the **surface area** of objects that are complex solids or polyhedral composites? (Levels C)

Basic Concepts:

Paper-and-pencil calculations can be used for Level A, but technology will be required for speedier and more accurate computations in Levels B & C. Students of all Levels (A-C) will master the following concepts:

1) using ratio & proportion to create a scale drawing;
2) multiplying & dividing decimals;
3) converting units of measure.

Prerequisite Skills:

To successfully complete Level A, students need to be able to:
-- multiply decimal numbers
-- determine an appropriate scale for a scale drawing
-- convert standard units of measure

To successfully complete Level B, students need Level A skills plus:
-- complete calculations using volume formulas for cylinders, cones and hemispheres
-- convert cubic units of measure

To successfully complete Level C, students need Level A & B skills plus:
-- complete calculations using surface area formulas for cylinders, cones and hemispheres.
-- convert square units of measure

Objectives:

Level A: Students will gain an understanding of the drafting requirements for constructing a scale drawing of the ET and SRB.

Level B: In addition to ***Level A*** objectives, students will become proficient in calculating volumes of cylinders, cones, and hemispheres.

Level C: In addition to ***Level A & B*** objectives, students will become proficient in calculating surface areas of cylinders, cones, and hemispheres.

FCAT Standards:

The following are the Sunshine State Standards (FCAT Standards) for each level. Standards that are primarily focused upon appear in **bold** type.

FCAT Standards (Grades 6 – 8):

Level A: *MA.A.1.3.1; MA.A.1.3.2; MA.A.3.3.1; MA.A.3.3.2; MA.A.3.3.3; MA.A.4.3.1; MA.B.1.3.3;* ***MA.B.1.3.4****; MA.B.2.3.2;* ***MA.B.4.3.1***

Levels B/C: *MA.A.1.3.1; MA.A.1.3.2; MA.A.3.3.1; MA.A.3.3.2; MA.A.3.3.3; MA.A.4.3.1; MA.B.1.3.3;* ***MA.B.1.3.4****; MA.B.2.3.2; MA.B.3.3.1;* ***MA.B.4.3.1****; MA.C.1.3.1; MA.C.3.3.1*

FCAT Standards (Grades 9 - 12):

Level A: *MA.A.1.4.1; MA.A.1.4.2; MA.A.3.4.1; MA.A.3.4.3; MA.A.4.4.1;* ***MA.B.1.4.3****;* ***MA.B.3.4.1****; MA.B.4.4.2;* ***MA.C.3.4.1****; MA.C.3.4.2*

Levels B/C: *MA.A.1.4.1; MA.A.1.4.2; MA.A.3.4.1; MA.A.3.4.3; MA.A.4.4.1;* ***MA.B.1.4.1****;* ***MA.B.1.4.3****;* ***MA.B.3.4.1****; MA.B.4.4.2;* ***MA.C.3.4.1****; MA.C.3.4.2*

Preparation:

Before beginning work, the teacher will discuss the appropriate mathematical concepts with the students. Depending on the level in which they participate, teacher and students will discuss: the construction of scale drawings & scale models; calculating the volumes of cylinders, cones, and hemispheres; calculating the surface areas of cylinders, cones, and hemispheres.

Materials:

Each student should have a pencil, ruler / protractor, compass, calculator (Levels B & C), sheet of graph paper, and the appropriate student worksheet. The teacher should also have access to a white / blackboard, an overhead projector (if using transparencies), or a computer & projector (if using MS PowerPoint). The teacher also will need film clips from a famous sci-fi film, such as a "Star Wars" or a "Star Trek" episode. A teacher "Travelogue" may be used (time permitting) to show how massive the buildings at Kennedy Space Center (KSC) need to be to accommodate the orbiter, ET, and SRB's for maintenance and refurbishing.

Time for Activity:

Teacher Travelogue (Optional) – ½ class period
Teacher Introduction – ½ class period
Student Work - 1½ class periods
Student / Teacher review of work – 1 class period

Engage:

The lesson will begin with the teacher showing clips from a famous sci-fi film, such as a "Star Wars" or a "Star Trek" episode. The teacher will explain that the space vehicles are not full-size mockups, but the scale models. The lesson will continue with pictures of the Space Shuttle's External Tank (ET) and Solid Rocket Boosters (SRB's). The teacher should ask:

1.) "How can I draw a scale model of the ET & SRB on graph paper?" (Levels A, B, C);

2.) "How can I figure out how many cubic inches / feet of fuel will be needed to fill the tanks?" (Level B & C);

3) "How could I figure out how many square inches / feet of foam is needed to cover the ET?" (Level C).

Explore:

The teacher will show (using overhead or computer projector) the blueprints for the ET & SRB (pp. 12-14 of student worksheets). Depending on the students' mathematical background and the Level (A, B, or C) being taught, the concepts of ratio, proportion, scaling, mapping, volume and surface area should be taught and / or reinforced. The class will "walk" through several possible scales to assure a drawing that will fit on 8½ by 11inch graph paper.

Explain:

The teacher will ask the class to define the key components of creating a scale model of a Shuttle fuel tank. The students should be able to name and explain such concepts as: consistency, using the same ratio or proportion, maintaining uniform units of measure, etc. At the end of the discussion, the teacher will ask the students to consider what would be the largest scale that could be used in drawing the ET.

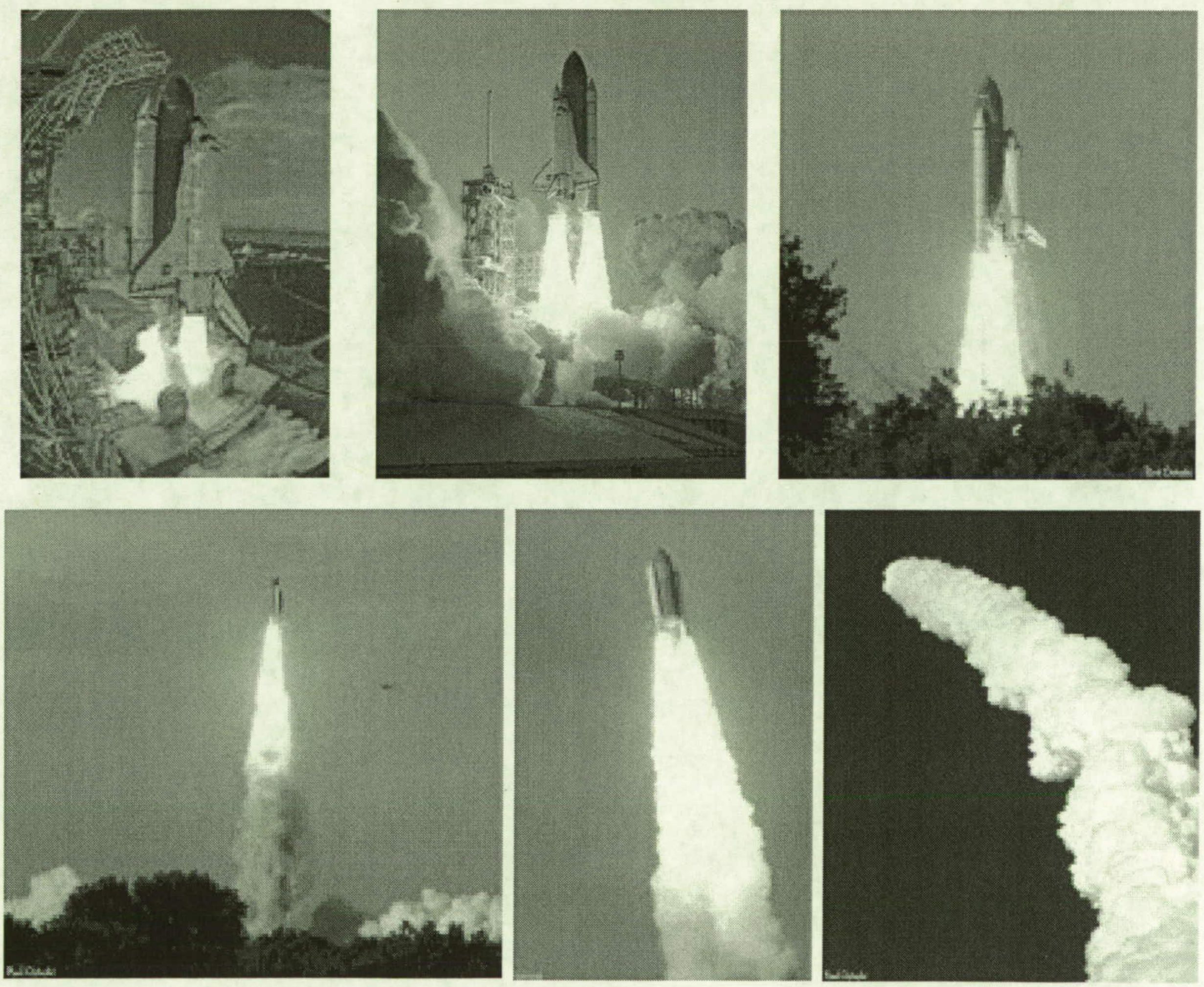
Evaluate:

After completing their worksheets, students will present their calculations and findings to the class. It is recommended that the teacher collect student "Shuttle ET & SRB Worksheets" for a grade, and use the 3 "Student Evaluations" (one for each level) as a means of further assessment. The teacher may proceed with re-teaching or enrichment (as needed) after analyzing students' work.

Extend:

To further students' understanding of creating scale models, the students will be asked to complete a Student Reflection Worksheet (of appropriate difficulty level) where they will explain what steps & processes they used in creating their scale drawing and in finding volumes & surface areas (Levels B & C).

Shuttle Atlantis from T+3 to T+60.



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Shuttle ET & SRB Math – Level C

Name *ANSWER KEY*
Period_____ Date __________

1. **On a sheet of graph paper, create a scale model of:**

   a.) the Shuttle's external fuel tank (ET). *Students' drawing should measure 10.25" by 1.84" (ten & one-quarter by approx. 1 & seven-eighths inches).*

   b.one of the Shuttle's solid rocket boosters (SRB). *Students' drawing should measure 9.25" by 0.81" (nine & one-quarter by approx. 13/26 inches).*

Use the following scale: 1 in. = 15 ft. Use your shuttle blueprints to find the appropriate dimensions.

2. **Explain (using complete sentences) what would happen if you changed the scale of you drawing to: 1 in. = 10 ft.**
   The ET and SRB would be too long to fit on the graph paper.

3. **Explain (using complete sentences) what would happen if you changed the scale of you drawing to: 1 in. = 40 ft.**
   The ET and SRB would be very small and could fit on a ¼ sheet of graph paper.

4. **Why is it important to use the right scale when making a scale drawing?**
   The right scale allows you to make your drawing large enough to see easily, while making sure the object fits on your graph paper.

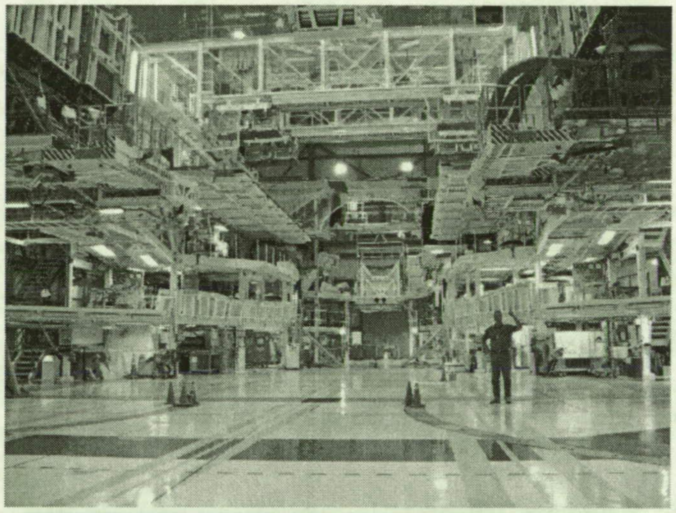
Shuttle ET & SRB Math - Level C Name ***ANSWER KEY***
Student Worksheet (page 2)

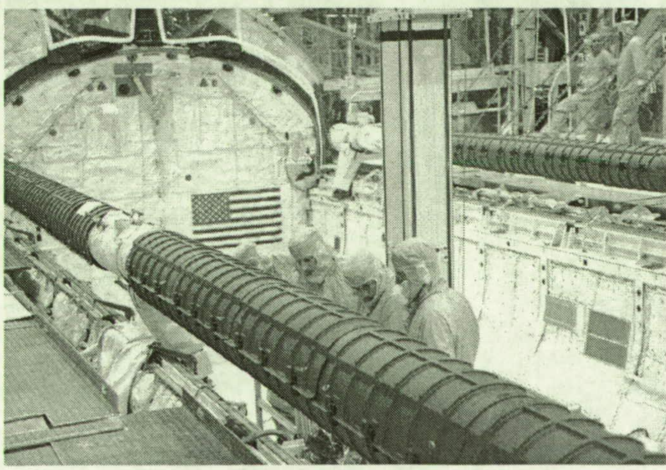
5. Calculate the volume of the ET using the formulas below. Use your shuttle blueprints to find the appropriate dimensions. Show ALL your work & computations (assume the nose cone of the ET is a cone, and $\pi = 3.14$).

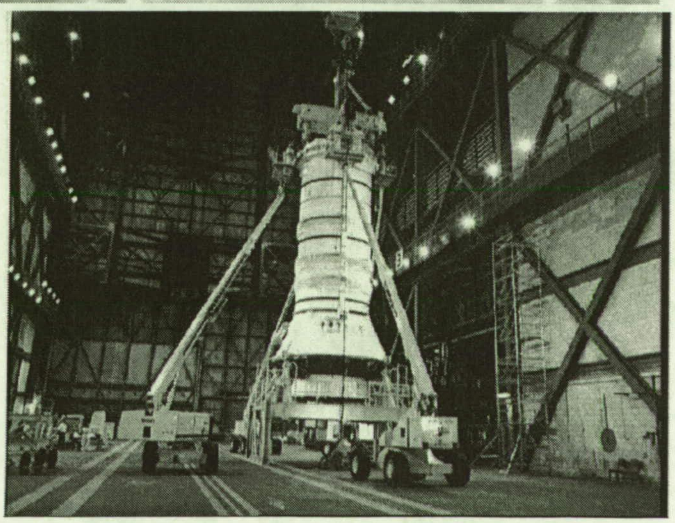
cylinder: $V = \pi r^2 h$ V_{cyl} = ***110,960,508.90*** in^3
hemisphere: $V = 2/3\ \pi r^3$ V_{hem} = ***9,506,472.28*** in^3
cone: $V = 1/3\ \pi r^2 h$ V_{cone} = ***11,234,399.92*** in^3

Total Volume ET = ***131,701,381.11*** in^3 **(or)** ***76,216.08*** ft^3

Calculations & Work Area:







Shuttle ET & SRB Math - Level C Name ***ANSWER KEY***
Student Worksheet (page 3)

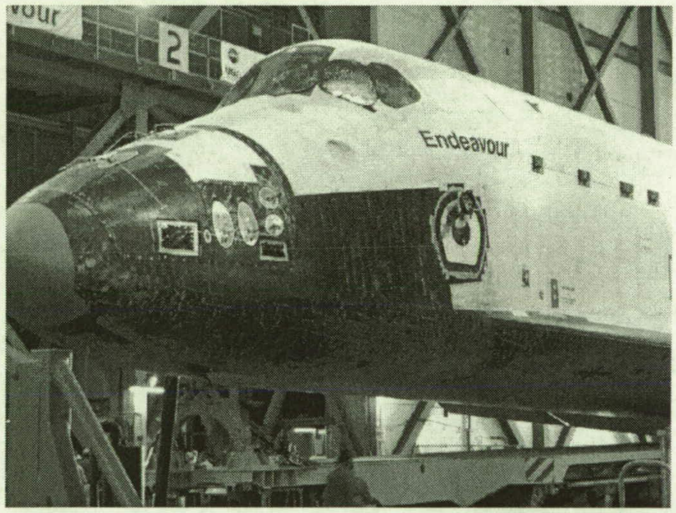
6. Calculate the volume of the SRB using the formulas below. Use your shuttle blueprints to find the appropriate dimensions. Show ALL your work & computations (assume the nose cone of the SRB is a cone, and $\pi = 3.14$).

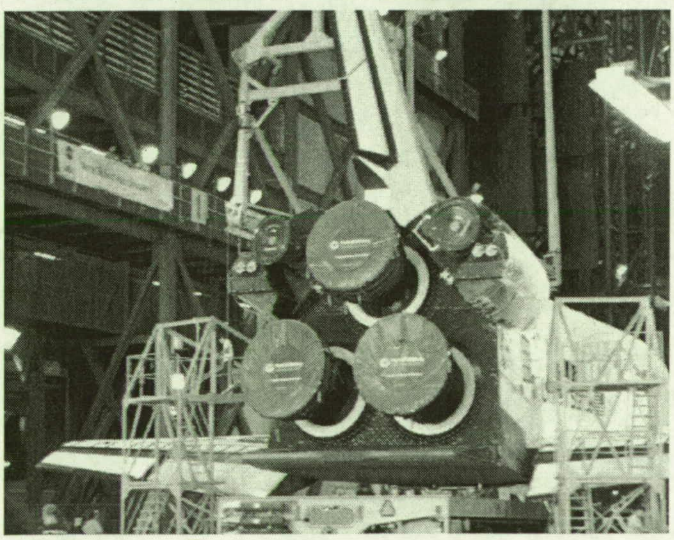
cylinder: $V = \pi r^2 h$ **V_{cyl} = *23,364,701.97* in^3**

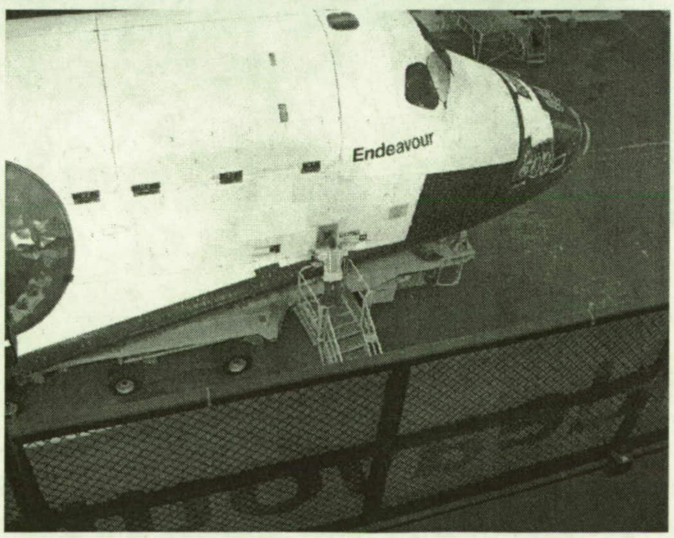
cone: $V = 1/3\ \pi r^2 h$ **V_{cone} = *1,545,084.23* in^3**

Total Volume SRB = *24,909,786.20* in^3 (or) *14,415.39* ft^3

Calculations & Work Area:







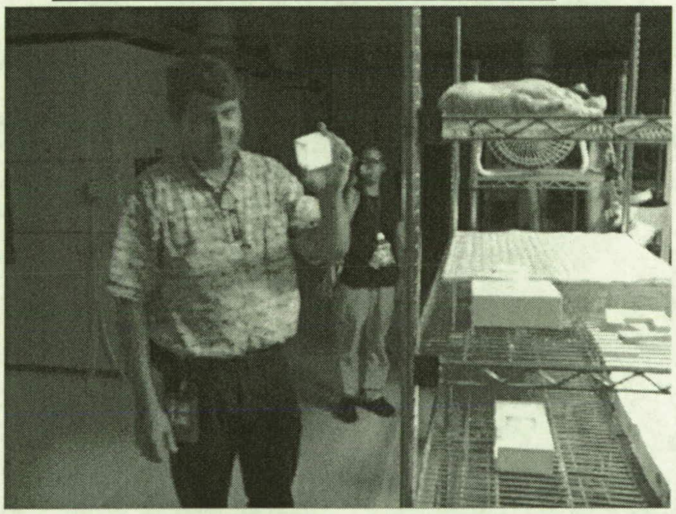
Shuttle ET & SRB Math - Level C Name ***ANSWER KEY***
Student Worksheet (page 4)

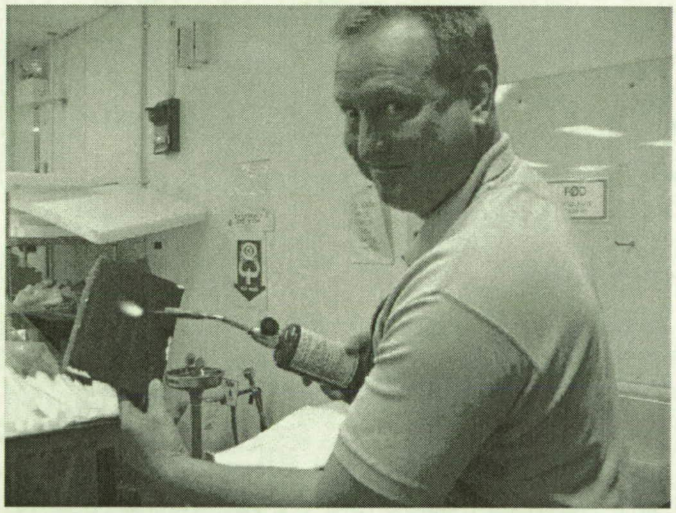
7. Calculate the surface area of the ET using the formulas below. Use your shuttle blueprints to find the appropriate dimensions. Show ALL your work & computations (assume the nose cone of the ET is a cone, and $\pi = 3.14$).

cylinder: $SA = 2\pi rh$ — SA_{cyl} = ***1,340,102.77*** in^2
hemisphere: $SA = 2\pi r^2$ — SA_{hem} = ***172,218.70*** in^2
cone: $SA = \pi lr$ — SA_{cone} = ***203,521.74*** in^2

Total ET Surface Area = *1,715,843.21* in^2 (or) *11,915.58* ft^2

Calculations & Work Area:





Shuttle ET & SRB Math - Level C Name ____________________

Student Worksheet (page 5)

8. Now that you have calculated the ET's surface area, find NASA's cost:

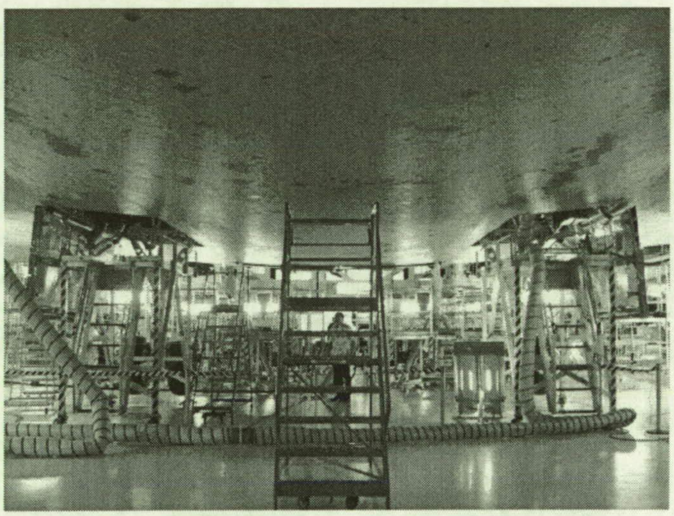
a.) per cubic inch (*round to nearest tenth of a cent*)

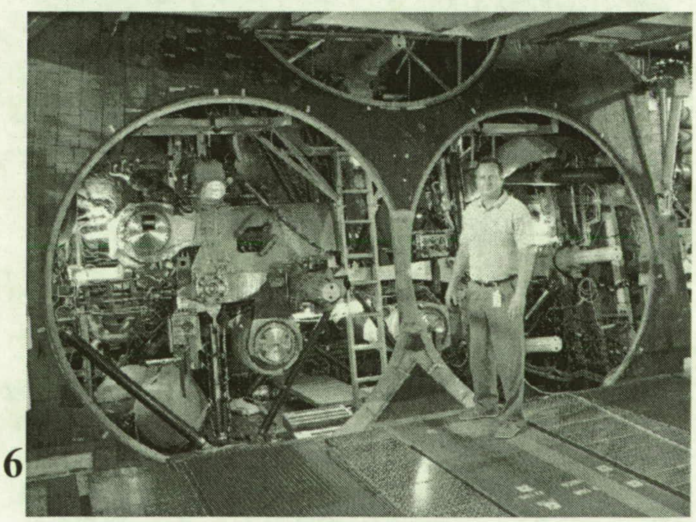
b.) per cubic foot (*round to the nearest cent*)

of spraying insulating foam. Average depth of foam: 1.25 inches. Cost of coating tank (materials & labor): $750,000.00

Cost per cubic inch: *34.96 or 35 cents* Cost per cubic foot: *$604.25*

Calculations & Work Area:





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Shuttle ET & SRB Math – Level C
Student Evaluation Sheet

Name ___________________________
Period ___ Date __________________

Directions: Please choose or write the BEST answer for each question.

1. At the scale of 1 in = 15ft, the drawing of the Shuttle's External Tank:
a) was too big for my paper
b) fit exactly width-wise
c) was too small to draw easily
d) fit exactly length-wise

2. At the scale of 1 in = 15ft, the drawing of the Shuttle's Solid Rocket Booster:
a) was too big for my paper
b) fit with room to spare
c) was too small to draw easily
d) fit exactly length-wise

3. The BEST way to find an appropriate scale for any scale drawing is to:
a) divide the object's length by the length of you paper
b) divide your paper's length by the object's length
c) guess-and-check
d) copy off of a friend

4. When converting cubic inches to cubic feet, you must:
a) multiply by 144
b) divide by 144
c) divide by 1728
d) multiply by 1728

5. Volume is ALWAYS measured in:
a) normal units
b) square units
c) cubic units
d) angstrom units

6. When converting square feet to square inches, you must:
a) multiply by 144
b) divide by 144
c) divide by 1728
d) multiply by 1728

7. Why would the technicians and engineers who build the ET and SRB for NASA need to have scale drawings of the two? Sample Answer: *The technicians and engineers would need to know the size, shape, and exact dimensions of what they needed to build. A scale drawing has everything laid out for them.*

8. Give two (2) examples of how you could use scale drawings in everyday life. Possible Answers: *Make a scaled floor plan of your room/ house so you can rearrange furniture without actually moving it; to do landscaping & know where all the plants would go; etc.*

Shuttle ET & SRB Math Name ______________________________
Student Reflection Sheet Period ___ Date ____________________

Now that you have finished your "Shuttle ET & SRB Worksheets", I want you to go back and reflect on the steps and procedures that you followed to come up with you final answers / conclusions.

Please write, in COMPLETE sentences, 3 to 4 paragraphs describing your journey, from initially reading the problem to completing the assignment.

If you completed LEVEL A, you MUST write about how you planned, drew, and completed your scale drawing <u>AND</u> how you came up with your answers for Questions 2 – 4.

If you completed LEVEL B, you may choose to write about the scale drawing & Questions 2 – 4, <u>OR</u> you may write about the steps you took to find the volumes of either the External Tank (ET) or the Solid Rocket Booster (SRB).

If you completed LEVEL C, you may do either of the above (Level A or B assignment) <u>OR</u> you may choose to write about how you figured out the surface area of the External Tank (ET).

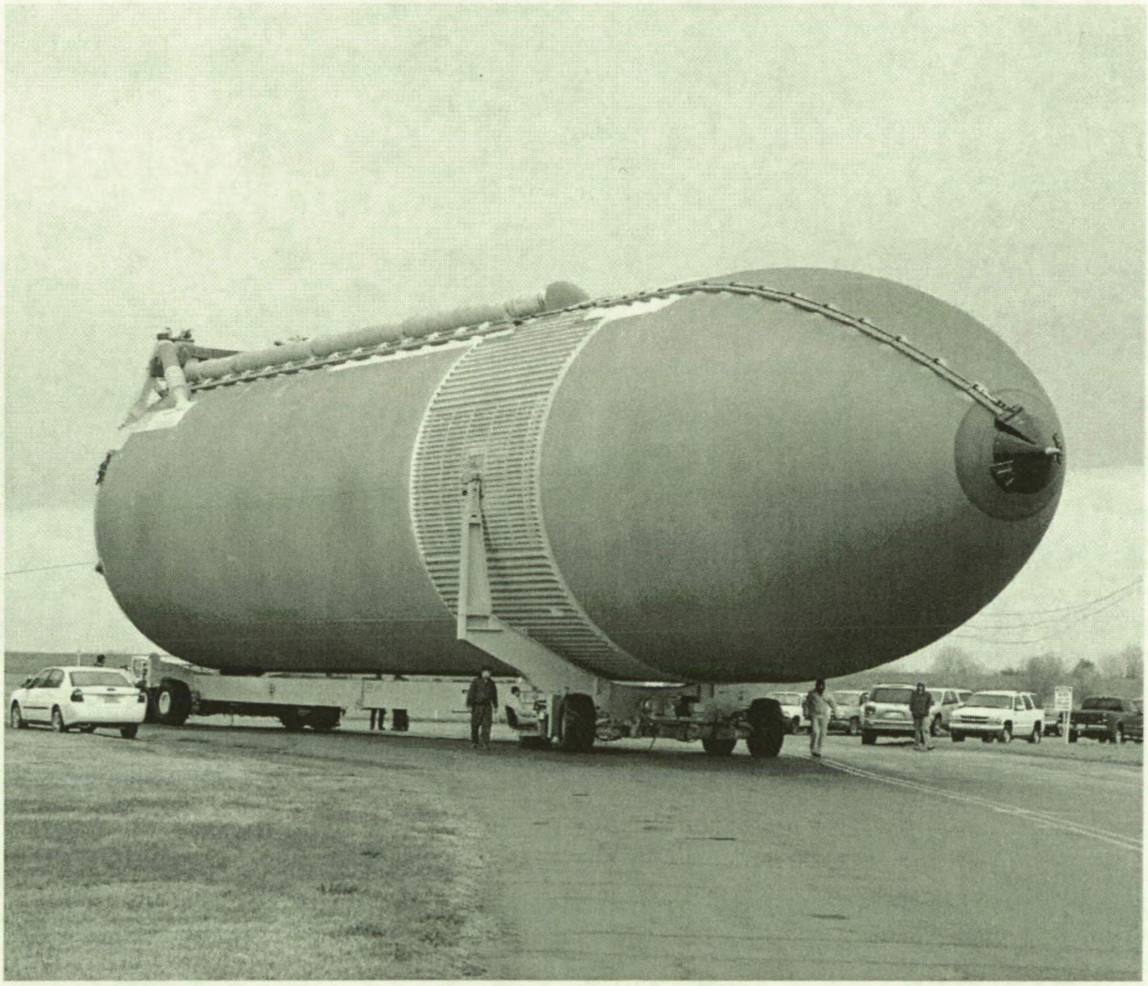
All case studies will be graded on the following rubric:

Spelling ------- (20%) - *Are all words spelled correctly?*
Grammar -----(20%) - *Do subjects/verbs agree? Are words/phrases used correctly?*
Clarity ---------(20%) - *Are your thoughts/ideas clearly understood?*
Coherence -----(20%) - *As a whole, do your thoughts/ideas flow logically?*
Completeness--(20%) - *Did you fully explain all steps used in arriving at your final answer?*

This assignment is due no later than _________________________, 2_____
Month Day Year

External Shuttle Fuel Tank

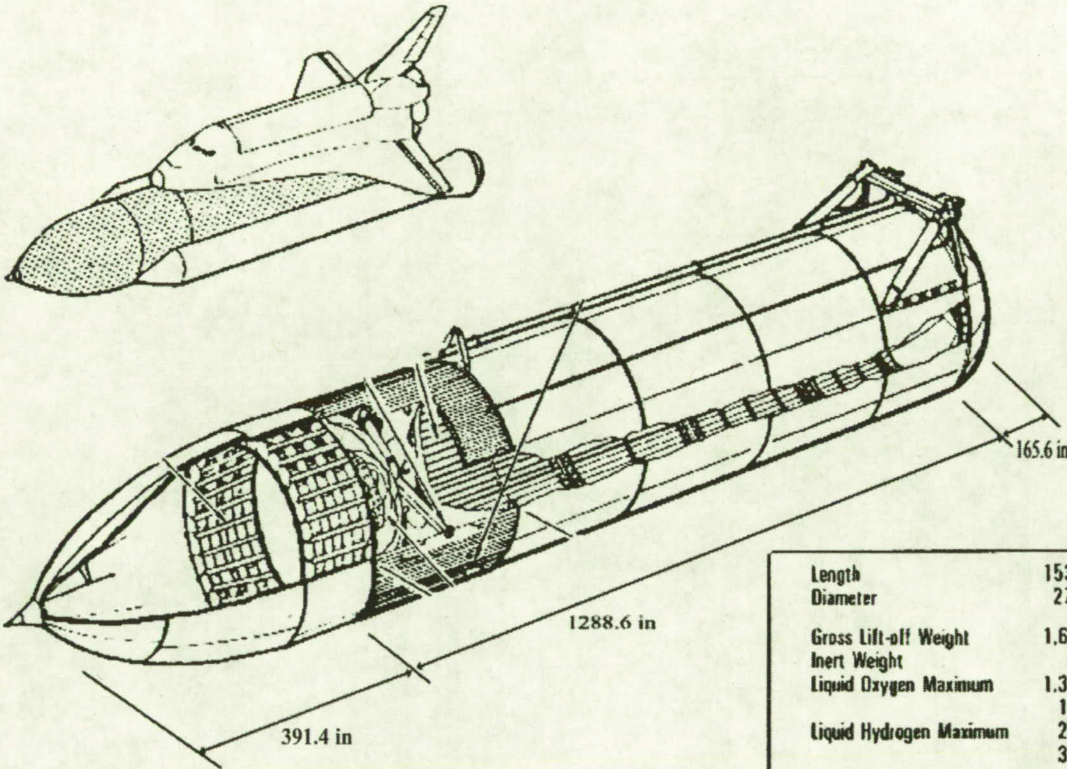
The External Tank (ET) is covered with a 1.5-inch thick protective covering of insulating foam. The foam keeps ice from forming on the ET's surface, and helps keep the 2 internal tanks containing liquid hydrogen (LH2) and liquid oxygen (LO2) at –423^{O}F and –293^{O}F respectively.



ET Stat's

Over-all Length	153.8 feet (1845.6 in)
Diameter	27.6 feet (331.2 in)

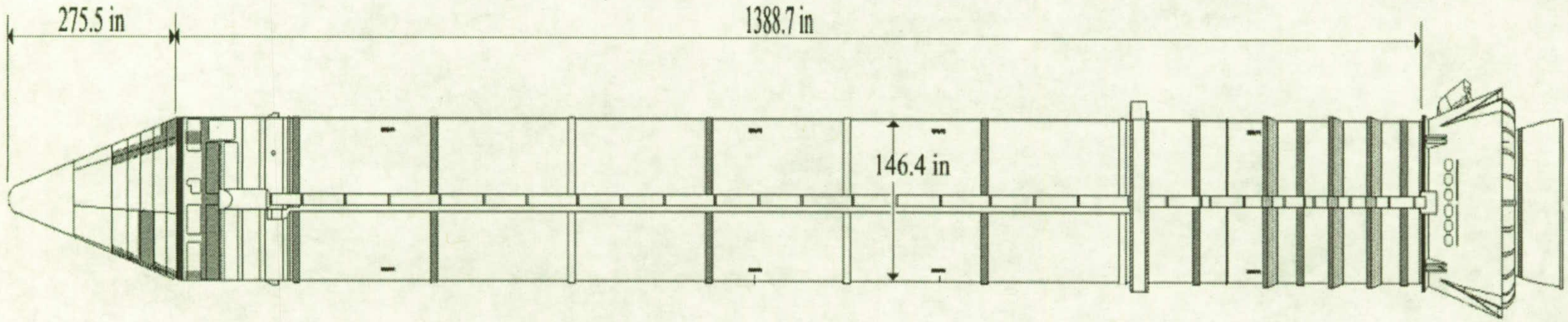
Shuttle & External Fuel Tank



Length	153.8 Feet
Diameter	27.6 Feet
Gross Lift-off Weight	1,655,600 Pounds
Inert Weight	66,000 Pounds
Liquid Oxygen Maximum	1,361,936 Pounds
	143,351 Gallons
Liquid Hydrogen Maximum	227,641 Pounds
	385,265 Gallons

(All Weights Approximate)

Lightweight External Tank



Solid Rocket Booster (SRB)

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United Space Alliance
8550 Astronaut Blvd
Cape Canaveral, FL 32920

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14. ABSTRACT

My name is Mike Prince and I was one of the eleven Brevard County teachers selected by United Space Alliance, LLC (USA), to work at the Kennedy Space Center (KSC) along side USA + NASA engineers during the Summer of 2007. Attached is a summary of my expierence

15. SUBJECT TERMS: External Tank - Solid Rocket Boosters

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