GRADES **2-4**

Space Shuttle Tiles

structures and materials

Aeronautics
Research
Mission
Directorate

Museum
in a
BOX
Series

(Photo courtesy of NASA - www.nasaimages.org)

Space Shuttle Tiles

Img. 1 The Space Shuttle Atlantis in orbit.

Lesson Overview

In this activity, students will calculate the number of tiles to cover an area of the shuttle (15 feet by 22 feet) as well as the weight of these tiles based on the shuttle tile included in the MIB. The students then determine the launch costs for the weight of the tiles determined.

SAFETY NOTE FOR SHUTTLE TILE:
The silica material in shuttle tiles is not classified as hazardous either by Federal SARA or CERCLA standards. However, material from the silica fiber layer can cause temporary irritation of the throat and/or itching of the eyes and skin so that touching a bare tile should be avoided. For your convenience, the tile is sealed in a protective plastic wrapping. The plastic wrap should not be removed. Never touch the shuttle tile. More information is available through MSDS (www.MSDS.gov).

Objectives

1. Calculate number and weight of materials, the same way scientists and engineers do.
2. Learn about cost measuring, using simple math operations.

Materials:

Included in MIB

Space Shuttle tile
Food scale

Provided by User

None

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Background

Shuttle Tiles

A key to a successful thermal protection system for the Space Shuttle depends on two things—light weight and the ability to withstand the high temperatures of reentry.

(Photo courtesy of NASA - www.nasaimages.org)

Img. 2 A close-up of the underside of the orbiter.

When the space shuttle de-orbits and begins to return to Earth, it faces a serious problem due to frictional heating. Protecting the shuttle and the crew from such heat is very important. When the shuttle reenters Earth's atmosphere at about 400,000 feet or about 122 km, it is traveling at about 25 times the speed of sound (Mach 25). It uses the friction of reentry to slow the shuttle down, but in doing so it pays a price in the form of frictional heating. Temperatures on the shuttle reach several thousand degrees. If the shuttle had a metal exterior like an airplane, it would be burn up due to the heat produced by the friction.

The tiles on the shuttle provide a means for thermal protection.

There are some 24,300 tiles that measure about six inches long on each side (15.25cm) and vary in thickness from 1 to 5 inches (2.54 to 12.7 cm) depending on where they are attached. They are made up of what is called a porous silicon material that is very light and extremely heat resistant. There are two main types of tiles, one a black-coated tile called HRSI for High-Temperature Reusable Surface Insulation tile. These tiles can withstand up to 2,300 degrees F (1,260 degrees C). They cover the bottom of the shuttle, areas around the forward windows, and several other key areas. The densities of these tiles range from 9-22 pounds per cubic foot.

(Photo courtesy of NASA - www.nasaimages.org)

The second type are white-coated tiles and are LowTemperature Reusable Surface Insulation (LRSI). They are made to insulate the shuttle up to 1,200 degrees F (650 degrees C). These tiles are usually larger and thinner, 8 inches long on each side (20.3cm) and from less than a half inch (1 cm) thick up to 1 inch (2.54 cm) in thickness. The densities range from 9 to 12 pounds per cubic foot.

The making of tiles begins with pure silica that comes from refined sand. This material is formed in fibers and mixed with pure water and other chemicals and then poured into a mold where the excess water is squeezed out.

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(Photo courtesy of NASA - www.nasaimages.org)

Img 5. A close-up of the tile numbering system.

This is then taken to the largest microwave oven in America located at the Lockheed Space Operations plant in Sunnyvale, California. After this they are treated in an oven at a temperature of 2,350 F (1,288 C). This process fuses the fibers without actually melting them.

The two types of tiles are essentially the same except for the coatings and cut. No two tiles are exactly alike. They fit by being trimmed to an exact size depending on its location on the shuttle. The tiles form the ultimate "jigsaw puzzle", only in this case, each piece is numbered so its location is easy to find.

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Activity 1   Analyzing Tiles

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Time Requirement: 30 minutes

Materials:

In the Box

Space Shuttle tile
Food scale

Supplied by user

None

Worksheets

Cost of Launching the
Space Shuttle Tiles
(Worksheet 1)

Reference Materials

None

Key Terms:

Friction

(Photo courtesy of NASA - www.nasaimages.org)

Img. 3 Replacing a shuttle tile.

Objective:

In this activity, students will learn how friction affects the space shuttle.

Activity:

1. Show students the picture of the space shuttle from the **Images** section at the end of this document. Ask the students to observe the tiles in the picture. Where have they seen tiles before? What are some uses for tiles? Ask the students to turn to a partner and discuss:

 a. Describe the tiles (What is their shape? Color? Are they all the same?)

 b. What do you think is the purpose of the tiles?

2. Ask the students to rub their hands together. What do they feel? (Students should observe that their hands become warm.) Explain that when objects rub against one another, the force of friction opposes the objects' motion. Friction causes heat. Ask the students to imagine the space shuttle returning to the Earth from the International Space Station. What does the space shuttle rub against as it enters the Earth's atmosphere? (This may take a bit of coaching, but the students should be able to arrive at the conclusion that the shuttle encounters friction due to the air.) Discuss how the friction between the shuttle and the air creates heat.

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3. Ask the students what protects the shuttle (and thus the astronauts inside) from the heat? (The tiles.) Can they think of anything that people might use on earth to protect them from heat? (Examples may be pot holders, fire fighters wear special suits, or insulating material in your house.)

4. Ask the students to describe common characteristics of heat insulating materials. Lead the students to infer that heat insulating materials are often (but not always) bulky and heavy.

5. Pass around the shuttle tile. The tile is very fragile and students should be instructed on how to handle the tile carefully. ***CAUTION: The tile must stay in the plastic bag!*** Ask the students to describe the tile to their partner as they are observing it. What do they notice? Is it heavy or light? Is its light weight surprising?

6. Ask the students to explain why a low tile weight would be advantageous for the space shuttle. (The greater the weight of the shuttle, the more energy and thus more money it takes to launch.)

7. Now we will calculate the cost to launch the shuttle tile into space!
   Note: Numbers in the following calculations are for example only. Class calculation will vary by individual tile.

    a. Determine the weight (in pounds) of the shuttle tile with a small scale that might be used to weigh foods.
   Tile weight: 0.8 lb

    b. Determine the area of the shuttle tile.

        1. Multiply the length times the width of the shuttle tile.
   Length • Width = Area
   $$6 \text{ in} \cdot 6 \text{ in} = 36 \text{ in}^2$$

        2. Divide the area (in square inches) by the number of square inches in a square foot (144) to determine the size of the area in square feet.

$$\frac{\text{Area in in}^2}{144 \text{ in}^2/\text{ft}^2} = \text{Area in ft}^2$$

$$\frac{36 \text{ in}^2}{144 \text{ in}^2/\text{ft}^2} = 0.25 \text{ ft}^2$$

    c. Assume the tiled surface area of the Space Shuttle is 15x22 feet. Determine the number of square feet in this area.

$$15 \text{ ft} \cdot 22 \text{ ft} = 330 \text{ ft}^2$$

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d. Calculate the number of tiles in this area by dividing the number of square feet in the area by the area of the shuttle tile (in square feet).

$$\frac{\text{Tiled area of shuttle}}{\text{Area of one tile}} = \text{number of tiles}$$

$$\frac{330 \text{ ft}^2}{0.25 \text{ ft}^2/\text{tile}} = 1320 \text{ tiles}$$

e. Determine the total weight in pounds for the number of tiles identified above.

Number of tiles • weight of one tile = total weight

1320 tiles • 0.8lbs/tile = 1056 lbs

f. It costs about $10,000 per pound to launch the shuttle into space. Determine the cost to launch the weight of the tiles into space.

Total weight • $10,000/lb = cost

1056 lbs • $10,000/lb = $10,560,000

Discussion Points:

Have the students explain why a thermal protection system is so important for human space flight.

1. Have the students explain why it is important to create a thermal protection system with the least weight possible.

2. Have the students discuss why it is so expensive to launch an object into orbit.

3. Have the students identify thermal protection systems in their homes or school used to keep the structure warm in the winter and cool in the summer. Have the students discuss what kind of costs they are saving with these systems.

4. Discuss ways to reduce friction. Have students look around the classroom and home and identify ways to reduce friction, such as oiling the hinges on doors, waxing skis, etc.

5. Invite a local firefighter to visit your classroom to demonstrate and discuss how he or she uses thermal protection gear.

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NATIONAL SCIENCE STANDARDS 2-4

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Motions and Forces

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

• Science and technology in society

NATIONAL MATH STANDARDS K-12

NUMBER AND OPERATIONS

• Understand numbers, ways of representing numbers, relationships among numbers, and number systems

• Understand meanings of operations and how they relate to one another

• Compute fluently and make reasonable estimates

ALGEBRA

• Represent and analyze mathematical situations and structures using algebraic symbols

• Use mathematical models to represent and understand quantitative relationships

MEASUREMENT

• Understand measurable attributes of objects and the units, systems, and processes of measurement

• Apply appropriate techniques, tools, and formulas to determine measurements.

DATA ANALYSIS AND PROBABILITY

• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them

PROCESS

• Problem Solving

• Communication

• Connections

• Representation

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Glossary

Acceleration:

is the rate of change of velocity. An object is accelerating if it is changing its velocity.

Energy:

is the capacity for doing work. You must have energy to accomplish work - it is like the "currency" for performing work. To do 1000 Joules of work, you must expend 1000 Joules of energy.

Friction:

is the surface resistance to relative motion, as of a body sliding or rolling.

Joule:

is the unit of energy equal to the energy exerted by a force of one Newton acting to move an object through a distance of one meter.

Kinetic Energy:

is the energy of motion

Mass:

is a measurement of how much matter there is in a body.

Newton:

is the unit of force equal to the force required to cause a mass of one kilogram to accelerate at a rate of one meter per second squared.

Power:

is the rate of doing work or the rate of using energy, which are numerically the same. If you do 100 Joules of work in one second (using 100 Joules of energy), the power is 100 Watts.

Work:

refers to an activity involving a force and movement in the direction of the force. A force of 20 Newtons pushing an object 5 meters in the direction of the force does 100 Joules of work.

Student Worksheets

Worksheet 1   Cost of Launching the Space Shuttle Tiles

1. Determine the weight (in pounds) of the shuttle tile with a small scale that might be used to weigh foods.

   Tile weight: [____] lb

2. Determine the area of the shuttle tile.

   1. Multiply the length times the width of the shuttle tile.

      Length • Width = Area

      [____] in • [____] in = [____] in²

   2. Divide the area (in square inches) by the number of square inches in a square foot (144) to determine the size of the area in square feet.

   $$\frac{\text{Area in in}^2}{144\ \text{in}^2/\text{ft}^2} = \text{Area in ft}^2$$

   $$\frac{[\quad]\ \text{in}^2}{144\ \text{in}^2/\text{ft}^2} = [\quad]\ \text{ft}^2$$

c. Assume the tiled surface area of the Space Shuttle is 15x22 feet. Determine the number of square feet in an area.

   15 ft • 22 ft = [____] ft²

d. Calculate the number of tiles in this area by dividing the number of square feet in the area by the area of the shuttle tile (in square feet).

   $$\frac{\text{Tiled area of shuttle}}{\text{Area of one tile}} = \text{number of tiles}$$

   $$\frac{[\quad]\ \text{ft}^2}{[\quad]\ \text{ft}^2/\text{tile}} = [\quad]\ \text{tiles}$$

e. Determine the total weight in pounds for the number of tiles identified in above.

   Number of tiles • weight of one tile = total weight

   [____] tiles • [____] lbs/tile = [____] lbs

f. It costs about $10,000 per pound to launch the shuttle into space. Determine the cost to launch the weight of the tiles in space.

   Total weight • $10,000/lb = cost

   [____] lbs • $10,000/lb = $ [_____]

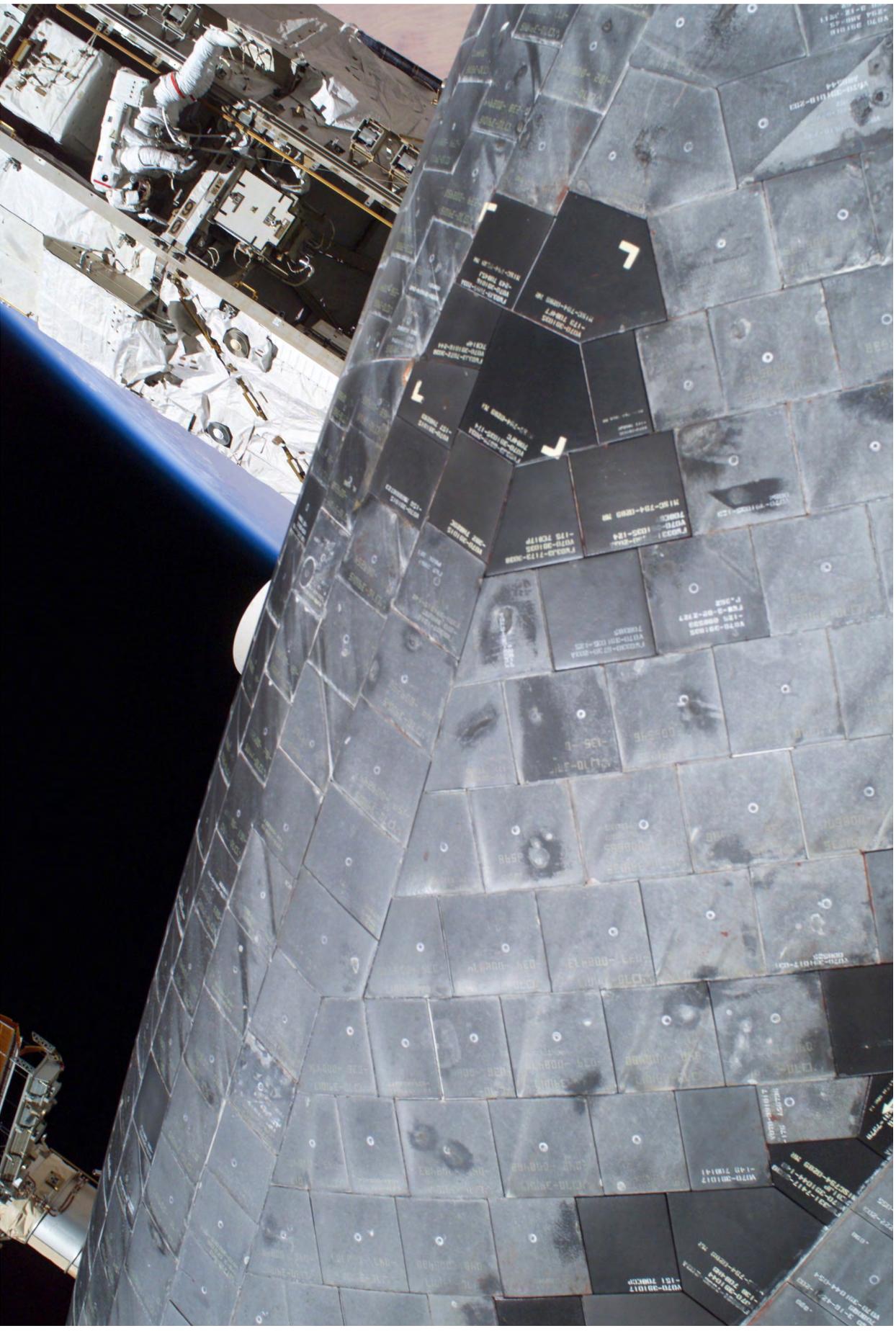Images

Img. 1 The Space Shuttle Atlantis in orbit.

(Photo courtesy of NASA - www.nasaimages.org)

Img. 3 Replacing a shuttle tile.
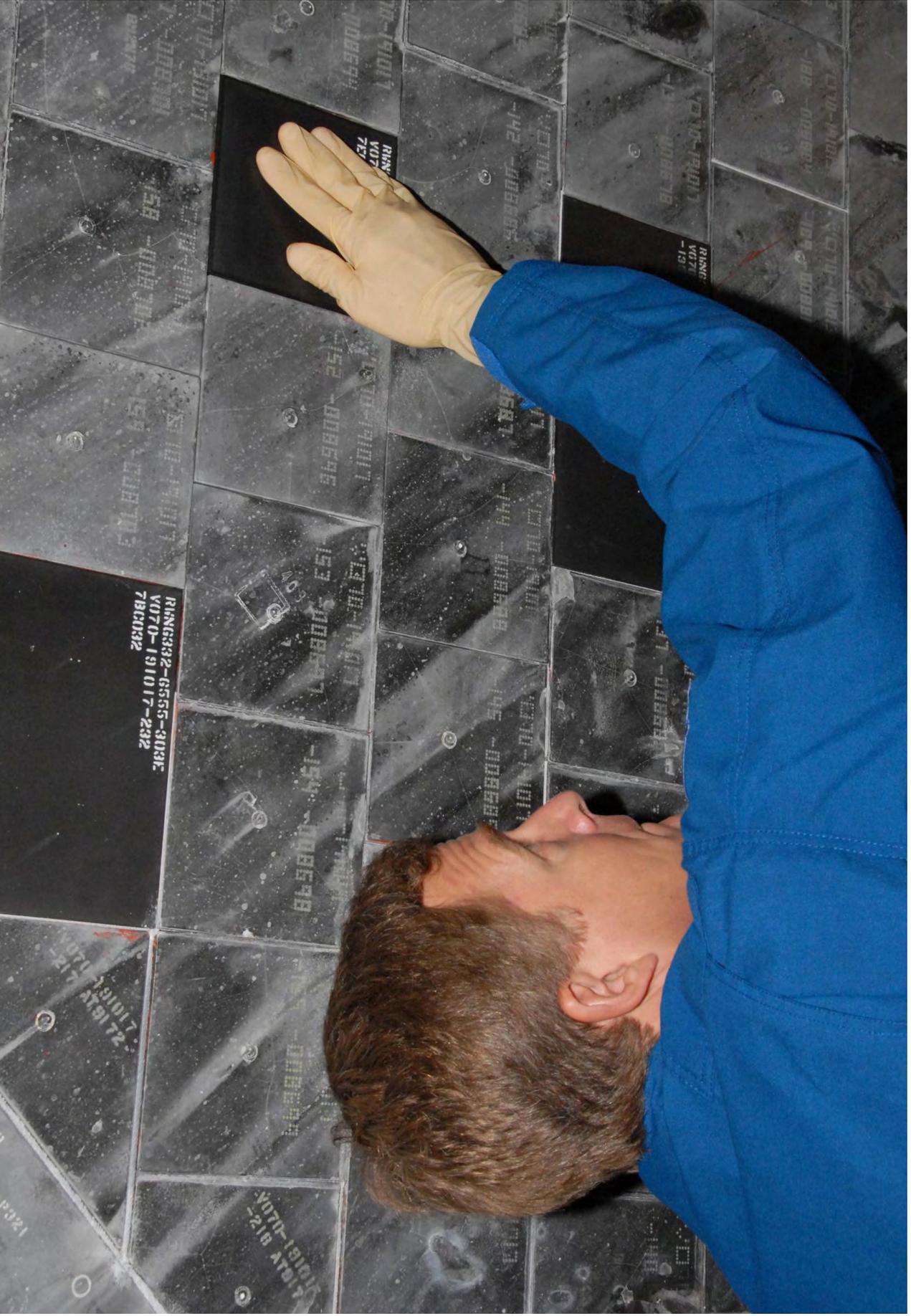
Img. 4 A damaged tile from Space Shuttle Endeavor. The tile was damaged on Mission STS-118 when a piece of foam from the external tank broke off during launch.

Img. 5 A close-up of the tile numbering system.
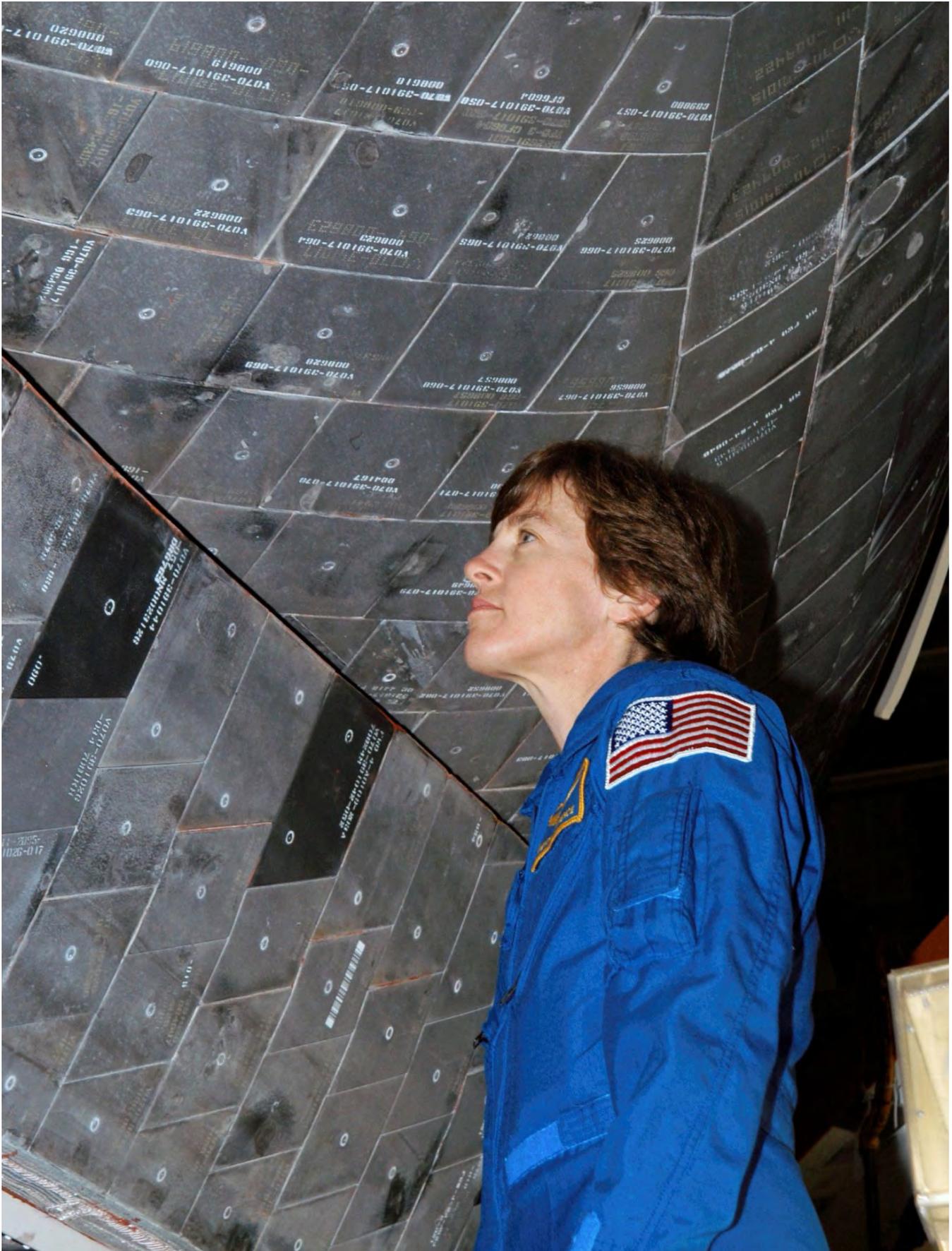
Img. 6 The underside of the Space Shuttle in orbit.

Img. 7 The underside of the Space Shuttle during re-entry.

MUSEUM IN A BOX – IMAGES

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