# Dynamic Design: A Collection Process

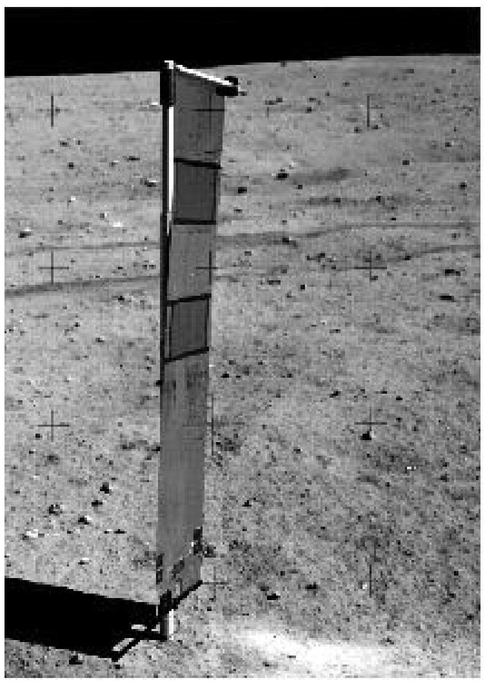
# It Began with Apollo
## A Brief History of Solar Wind Sample Return

## STUDENT TEXT

**Apollo Collector Design**

The first collectors for solar wind sample return were made for the Apollo lunar missions from 1969 to 1972. The Apollo solar wind collection (SWC) experiment consisted of an aluminum metal foil that was deployed to collect a sample of solar wind. This procedure allowed scientists to measure the composition of the solar wind on the lunar surface. The SWC equipment was manufactured by the Swiss National Science Foundation at the University of Bern, a partner in the Genesis mission. The foil weighed 130 grams and had an area of 4200 $cm^2$ (30 cm x 140cm). It was deployed on a five-section telescopic pole and unrolled. The foil was stored inside the collapsed pole when taken to the moon. The pole and foil had a total weight of 430 grams for each mission except Apollo 16, which was 450 grams. The pole was 4 cm in diameter and 40 cm in length when collapsed and 1.5 meters long when deployed.

**Figure 1**



NASA

*The SWC foil used on Apollo 16 had some sections of platinum, which allowed for easier cleaning operations on Earth. (AS-16-117-18849).*

Purity of the foil was critical to avoid contamination of the lunar samples and background contamination of the experiment itself. The Apollo 16 (see Figure 1) experiment was composed of both aluminum and platinum foils. The platinum foil allowed for treatment with dilute hydrofluoric acid before sample analysis on Earth to remove dust contamination. This treatment allowed for a more accurate analysis of solar wind particles that embedded into the foil by removing more of the surface contaminants as well as some solar wind from the outer portion of the foil. This process provided a more accurate picture of the solar wind that was collected.

**Deploying the Experiment**

On every Apollo mission, the solar wind experiment was conducted in a similar fashion to ensure consistency. The telescopic pole was extended and the five sections locked automatically. The reel was then pulled out, and the foil was unrolled and fastened to a hook near the lower end of the pole. The pole was planted upright into the ground, but it did not necessarily have to be at a perfect 90° angle with the moon's surface. It was important that the correct side of the foil was facing the sun. One side of the foil was marked with the word "SUN," which was pointed at the sun.

The following is the conversation that occurred during the Apollo 11 deployment of the solar wind collector. Eric Jones, an astronomer with the Los Alamos National Laboratory, transcribed the conversations as journal entries. Journal entries for all Apollo missions can be found on-line. The entire text can be found at http://www.hq.nasa.gov/office/pao/History/alsj/a11/a11.step.html#1100253. The number that precedes each speaker's name refers to the time index of the mission. The speakers are astronaut Buzz Aldrin, Mission Control Capsule Communication Bruce McCandless, and astronaut Neil Armstrong.

**Box 1**

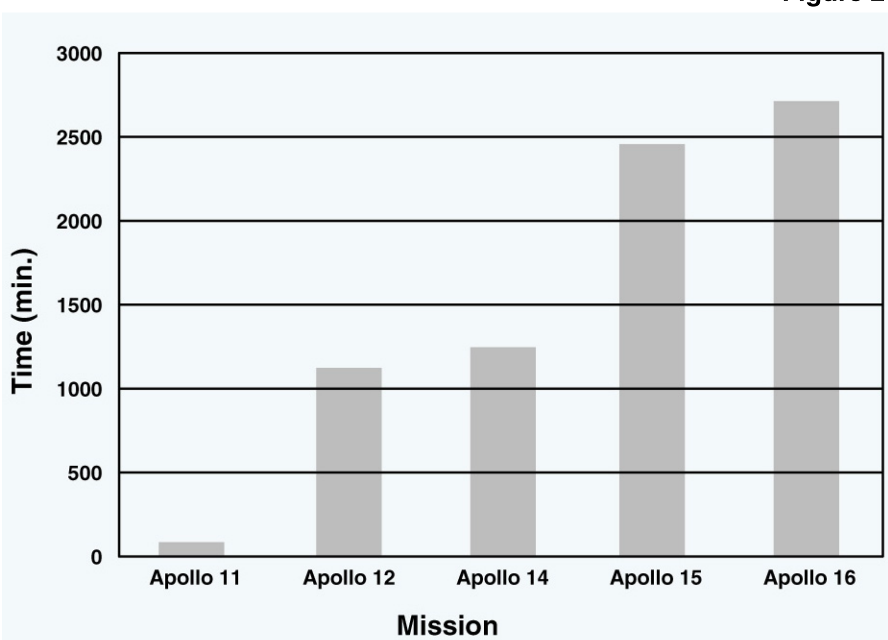
110:03:20 Aldrin: "Okay. You can make a mark, Houston." (Garbled)
110:03:24 McCandless: "Roger. Solar wind." (Pause)
[As per his checklist, Neil stops to take a pair of pictures of Buzz with the Solar Wind Collector. The pictures are AS11-40-5872 (**)
http://www.hq.nasa.gov/office/pao/History/alsj/a11/as11-40-5873.jpg
See a video of the deployment at:
http://www.hq.nasa.gov/office/pao/History/alsj/a11/a11.v1100253.mov
(Be aware this takes over five minutes to load and is a very short movie.)

110:03:36 Aldrin: "And, incidentally, you can use the shadow that the staff makes to assist you getting it perpendicular." (to the sun line) (garbled)

110:03:50 McCandless: "Roger. "(Long Pause)
[Aldrin, from the 1969 Technical Debrief - "In putting [the SWC pole] in the ground, it went down about 4 or 5 inches. It wasn't quite as stable as I would have liked it to have been, but it was adequate to hold it in a vertical position...Once you go past a depth of 4 or 5 inches, the ground gets quite hard. However, I didn't get much of a cue to this at this point while installing the solar wind experiment."]

The Apollo collector device foils were exposed for different durations (see Figure 2). It was exposed for 77 minutes on Apollo 11, 18 hours, 42 minutes on Apollo 12, 21 hours on Apollo 14, 41 hours, 8 minutes on Apollo 15, and 45 hours, 5 minutes on Apollo 16.

**Figure 2**



**Retrieval**

The reel was spring-loaded to facilitate rewinding the foil. The foil was able to be retracted similar to a window shade or an overhead projection screen. It was detached from the telescopic pole, placed in a Teflon™ bag, and placed in a sample return container. The pole was not taken back to Earth. Each mission had varying amounts of success when trying to retrieve the foil. During his 1969 debriefing Buzz Aldrin states:

**Box 2**

> "The solar wind disengaged from its staff quite easily. When it rolled up, it had a tendency to sneak off to the side and crinkle on the edges. I spent some 20 to 30 seconds unrolling it and trying to get it a little smoother. I then remembered that they really didn't care about exact neatness. All they wanted was the material back, because they were going to cut it up in many pieces anyway. So I just bunched it together and it slid into its container (the Teflon™ bag) fairly easily."

For a short video of Buzz Aldrin retrieving the solar wind collector go to:
http://www.hq.nasa.gov/office/pao/History/alsj/a11/a11.clsout.html

The difficulty in rolling up the foil after collection varied from one mission to another. Apollo 12 astronaut Alan Bean had a tougher time rolling up the foil from that mission's SWC. He described the need to have the foil and tape looked at in lunar conditions for future missions. Astronauts Alan Bean and Pete Conrad are speaking with mission control's Ed Gibson:

**Box 3**

134:55:26 Bean: "Solar wind doesn't like to roll up much. (Pause) Little rascal, doesn't want to roll up. (I'll) just wrap it around here best I can, without getting any dirt on it." (Pause)

134:56:13 Bean: "Okay. We got that solar wind."

134:56:17 Conrad: "Good boy!"

134:56:20 Bean: "Houston, we got that solar wind, but it didn't roll up in a very neat package."

134:56:26 Gibson: "Roger, Al. We copy. That's all right." (Long Pause)

134:56:46 Conrad: "Hey, it sure didn't, did it?"

134:56:48 Bean: "No. It just didn't. It split right near the top."

134:56:50 Conrad: "Can I help you?"

134:56:51 Bean: "Yeah. You can hold that, and I'll just try to roll it up as best I can without getting any...I already got a little dirt on it that's not doing any good. (Pause) You see what I mean?"

134:57:02 Conrad: "Yeah."

134:57:03 Bean: "Not a lot I can do about it. I'm sure it's [the solar wind] a good experiment. That thing is fragile."

134:57:09 Conrad: "Here, let me hold this end, and you just wrap it tight. That a boy."

134:57:14 Bean: "I'll squeeze it down."

[This is probably where Al is compressing the roll with his hands to get it tight enough to fit in the bag.]

134:57:15 Conrad: "That a..."

134:57:16 Bean: "And chase down any of those noble gases or whatever that crud is. Okay. Stick that in there? (To Gibson) Looks bad, but I think it will do the job, Houston. We squashed it in so it's..."

[continued below]

**Box 3 (continued)**

[The experimenters are looking for relative abundances of isotopes of helium, argon, and neon, the chemically-inert noble gases in the solar wind.]

134:57:27 Conrad: "Where is it [the bag]?"

134:57:29 Bean: "It's right...Let me get it for you."

134:57:32 CapCom: "Roger, Al."

134:57:34 Bean: "There you go. Okay. It just doesn't look so good, Houston."

Bean and Conrad could not get the foil to roll up automatically. They finally used their hands to roll it, and as a result the foil was soiled by the dirt adhering to their gloves. After it was rolled, they discovered that it was too big to fit into the container that was to be used to return it, and had to crush it with their hands. Upon inspection during the second EVA they decided that the foil tended to "set" and that it would not roll up because the set was stronger than the tension of the roller.

Alan Bean said during his technical debrief:

**Box 4**

“I would like to recommend that, before the next flight goes up, somebody take a look at what is actually happening to that foil as it sits out in the lunar environment. It may not be the foil that's presenting the problem. It might be (that) the tape that they are using on it actually cracks or gets stiff or something. It may be the same effect they are seeing in those Teflon™ bags.”

On subsequent Apollo missions the retrieval of the SWC had varying degrees of success. On Apollo 14, half of the foil rolled up automatically. Apollo 15 the astronauts had to roll all of the foil manually because it would not roll up mechanically. There was no reported difficulty recovering the Apollo 16 foil.

Although there were no design changes for the retrieval of the experiment, the Apollo 16 foil was made of platinum and aluminum so that it could be cleaned with hydrofluoric acid in order to remove dust. The need for cleaning may have been a result of dust getting onto the foil during the retrieval procedure in previous missions.

Questions:

Write your answers in your journal. Be prepared to discuss.

1. Describe the design of the Apollo foil experiments in your own words.

2. Describe how the astronauts deployed and retrieved the SWC.

3. Suppose you were an engineer and heard Alan Bean's recommendation during his technical debrief. Describe the steps you would take to help remedy the problem of retrieving the SWC.

GENESIS

SEARCH FOR ORIGINS

# Dynamic Design: A Collection Process

## It Began with Apollo

**Student Text Supplement**

## It Began with Apollo

*Apollo 11* *NASA*

## Solar Wind Collection Experiment

## Apollo 11


*Apollo 11 Mission Patch* *NASA*

*Buzz Aldrin* *NASA*

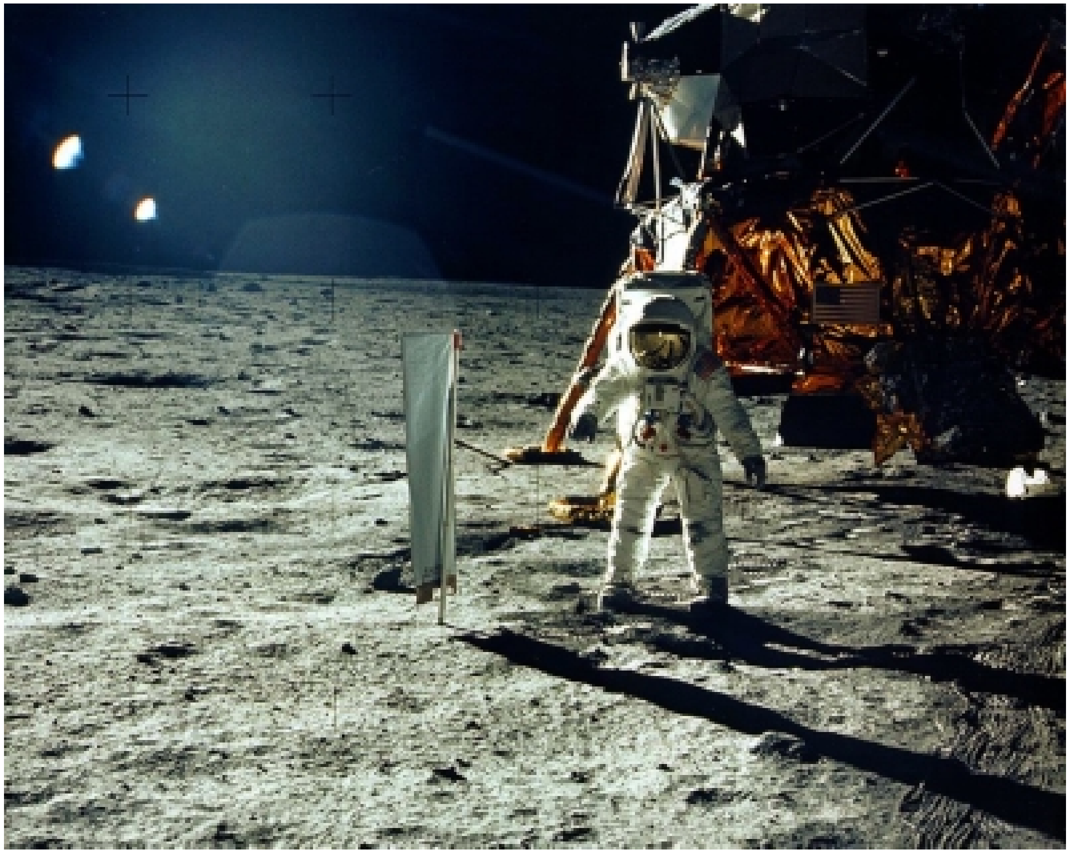
**Aldrin: “Okay. You can make a mark, Houston.” (Garbled)**

**McCandless: "Roger. Solar wind." (Pause)**

*Bruce McCandless* *NASA*

## Dynamic Design: A Collection Process

### It Began with Apollo



*NASA*

**[As per his checklist, Neil stops to take a pair of pictures of Buzz with the Solar Wind Collector.]**

*Buzz Aldrin* *NASA*

**Aldrin: "And, incidentally, you can use the shadow that the staff makes to assist you getting it perpendicular." (to the sun line) (Garbled)**

**McCandless: “Roger.” (Long pause)**

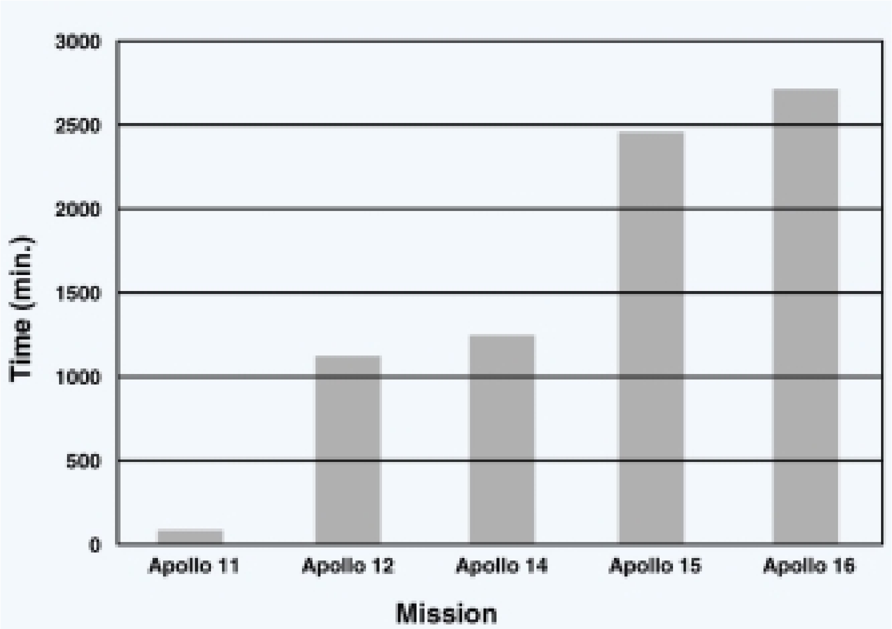
*Bruce McCandless* *NASA*

## It Began with Apollo

*Buzz Aldrin* *NASA*

**[Aldrin, from the 1969 Technical Debrief]: "In putting [the SWC pole] in the ground, it went down about 4 or 5 inches. It wasn't quite as stable as I would have liked it to have been, but it was adequate to hold it in a vertical position…Once you go past a depth of 4 or 5 inches, the ground gets quite hard. However, I didn't get much of a cue to this at this point while installing the solar wind experiment."**

## It Began with Apollo




**The Apollo collector device foils were exposed for different durations. It was exposed for 77 minutes on Apollo 11, 18 hours, 42 minutes on Apollo 12, 21 hours on Apollo 14, 41 hours, 8 minutes on Apollo 15, and 45 hours, 5 minutes on Apollo 16.**

*Buzz Aldrin* *NASA*

**Aldrin: "The solar wind disengaged from its staff quite easily. When it rolled up, it had a tendency to sneak off to the side and crinkle on the edges. I spent some 20 to 30 seconds unrolling it and trying to get it a little smoother. I then remembered that they really didn't care about exact neatness. All they wanted was the material back, because they were going to cut it up in many pieces anyway. So I just bunched it together and it slid into its container (the Teflon™ bag) fairly easily."**

## Solar Wind Collection Experiment

## Apollo 12


*Apollo 12 Mission Patch* *NASA*

*Alan Bean* *NASA*

**Bean: “Solar wind doesn’t like to roll up much. (Pause) Little rascal, doesn’t want to roll up. (I’ll) just wrap it around here best I can, without getting any dirt on it.” (Pause)**

**“Okay, we got that solar wind.”**

*Pete Conrad* *NASA*

## Conrad: “Good boy!”

## It Began with Apollo

*Alan Bean* *NASA*

**Bean: "Houston, we got that solar wind, but it didn't roll up in a very neat package."**

*Launch Control Center, NASA Kennedy Space Center*

**Gibson: "Roger, Al. We copy. That's all right."**
**(Long pause)**


*Pete Conrad* *NASA*

**Conrad: "Hey, it sure didn't, did it?"**

*Alan Bean* *NASA*

**Bean: “No. It just didn’t. It split right near the top.”**


*Pete Conrad* *NASA*

## Conrad: “Can I help you?”

# Dynamic Design: A Collection Process

## It Began with Apollo


*Alan Bean* *NASA*

**Bean: "Yeah. You can hold that, and I'll just try to roll it up as best I can without getting any…I already got a little dirt on it that's not doing any good. (Pause) You see what I mean?"**

# Dynamic Design: A Collection Process

## It Began with Apollo


*Pete Conrad* *NASA*

**Conrad: "Yeah."**

## It Began with Apollo

*Alan Bean* *NASA*

**Bean: “Not a lot I can do about it. I’m sure it’s [the solar wind] a good experiment. That thing is fragile.”**


*Pete Conrad* *NASA*

**Conrad: “Here, let me hold this end, and you just wrap it tight. That a boy.”**

*Alan Bean* *NASA*

## Bean: "I'll squeeze it down."


*Pete Conrad* *NASA*

## Conrad: "That a…"


*Alan Bean* *NASA*

**Bean: "And chase down any of those noble gases or whatever that crud is. Okay. Stick that in there? (To Gibson) Looks bad, but I think it will do the job, Houston. We squashed it in so it's…"**

# Dynamic Design: A Collection Process

## It Began with Apollo

*Pete Conrad* *NASA*

**Conrad: "Where is it [the bag]?"**

*Alan Bean* *NASA*

**Bean: "It's right…Let me get it for you."**

## It Began with Apollo

*Launch Control Center, NASA Kennedy Space Center*

## CapCom: "Roger, Al."


*Alan Bean* *NASA*

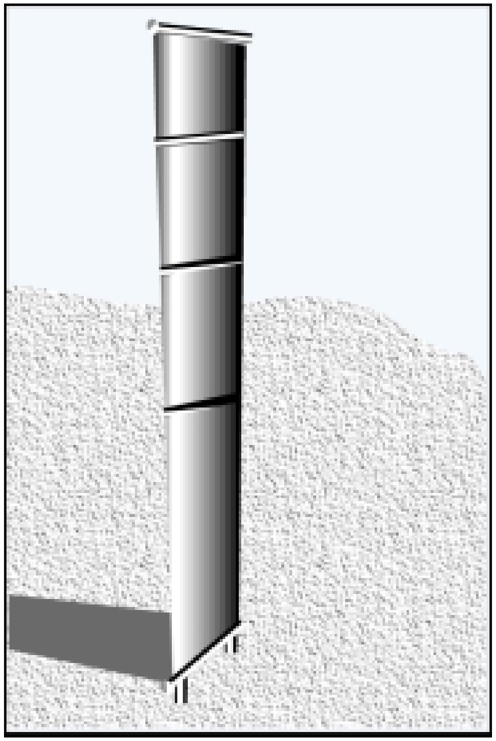
**Bean: "There you go. Okay. It just doesn't look so good, Houston."**

Alan Bean NASA

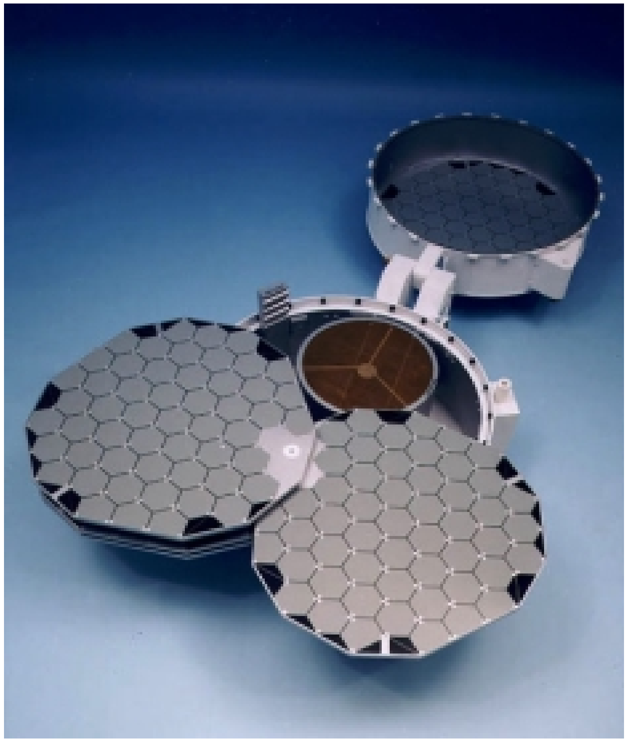
**[Alan Bean during his technical debrief]: "I would like to recommend that, before the next flight goes up, somebody take a look at what is actually happening to that foil as it sits out in the lunar environment. It may not be the foil that's presenting the problem. It might be (that) the tape that they are using on it actually cracks or gets stiff or something. It may be the same effect they are seeing in those Teflon™ bags."**

# Dynamic Design: A Collection Process

## It Began with Apollo



*ApolloType Solar Wind Collector Foil McREL*



*Genesis mission collector arrays and concentrator NASA*

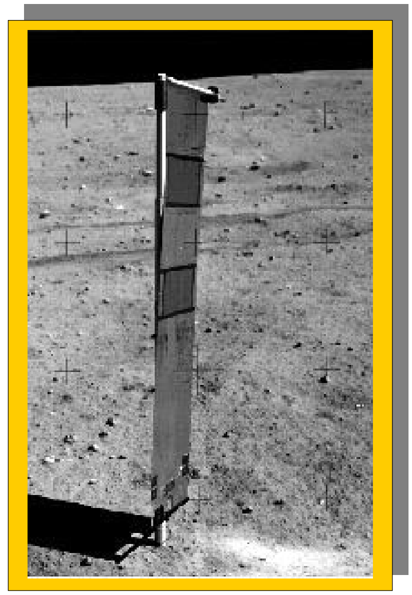
## Dynamic Design: A Collection Process

# It Began with Apollo

## A Brief History of Solar Wind Sample Return

## TEACHER GUIDE: POWERPOINT PRESENTATION

### BACKGROUND INFORMATION



NASA

The PowerPoint presentations that are provided as Genesis educational technology applications should be used as a supplement to the student texts from which they were derived. They offer an alternative way of assisting student learning of information contained in the text.

In constructing PowerPoint presentations, adding too much text to the slide is not visually pleasing to the student. Because sharing slide notes is vital for complete understanding of the concepts, notes are provided for the teacher. Therefore it is important to read and print out the slides and the teacher talking points that accompany them.

While showing the slides to your students, we encourage you to use the teacher talking points that accompany the slides. Ask the students to consider the graphics that are on each slide. The images and graphs that accompany the text will generate questions that can be explored further, either in the student text itself or with additional research.

### NATIONAL SCIENCE STANDARDS ADDRESSED

**Teaching Standards**

*Teaching Standard A: Teachers of science plan an inquiry-based science program for their students*

Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities and experiences of students.

Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.

*Teaching Standard B: Teachers of science guide and facilitate learning*

Focus and support inquiries while interacting with students.

Orchestrate discourse among students about scientific ideas.

Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas, and skepticism that characterize science.

*Teaching Standard D: Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science*

Create a setting for student work that is flexible and supportive of science inquiry.

Make the available science tools materials, media, and technological resources accessible to students.

**Content Standards**

**Grades 5-8**

*Science and Technology*

Understandings about science and technology

*History and Nature of Science*

History of Science

**Grades 9-12**

*Science and Technology*
Understandings about science and technology

*History and Nature of Science*
Science as a human endeavor
Nature of science and scientific knowledge
History of science and historical perspectives

*(View a full text of the National Science Education Standards.)*

## MATERIALS

For the Teacher

- Computer with Microsoft® PowerPoint application
- Computer projector or overhead projector with LCD Panel
- "It Began with Apollo" PowerPoint presentation

For each student

- Copy of Student Text, "It Began with Apollo"

## PROCEDURE

- The "It Began with Apollo" student text is to be used with the "Finding the Perfect Fit" activity in the Genesis science education module *Dynamic Design: A Collection Process*. The text provides a historical perspective of solar wind collection focusing on the solar wind experiments deployed during the Apollo missions. In the teacher guide for "Finding the Perfect Fit," it is recommended that this student text be used to introduce the activity. Follow the first three procedures in the teacher guide. The PowerPoint presentation "It Began with Apollo" can be used to accompany the student text. It would be especially helpful for the teacher to have students perform the dialogue like a play. If you choose to do this, the PowerPoint presentation can be used like cue cards.

- You may want to use this PowerPoint presentation with your students during an oral reading of the text. The slides could be used to show what the people look like in a way that students can relate.

- As an extension you may want to ask interested students to research other experiments that were deployed on the moon. Then look for dialogue from the astronauts involved in that experiment in the Apollo Lunar Surface Journal to create a PowerPoint similar to the one presented here.

## TEACHER RESOURCES

http://www.genesismission.org/educate/kitchen/techappl/invigor.html
Invigorate Your Presentations

http://www.hq.nasa.gov/office/pao/History/alsj/frame.html
Apollo Lunar Surface Journal

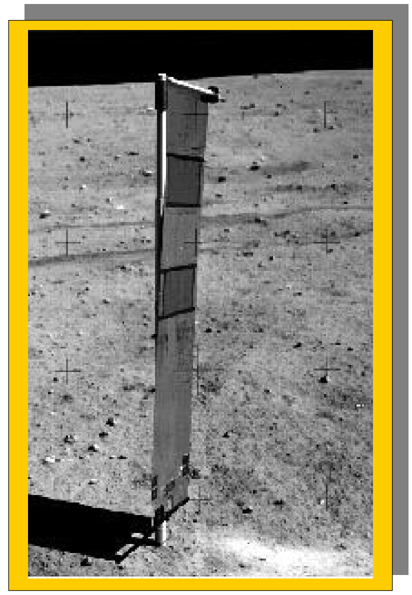
Dynamic Design:
A Collection Process

# It Began with Apollo

## A Brief History of Solar Wind Sample Return

## TEACHER NOTES: POWERPOINT PRESENTATION

### BACKGROUND INFORMATION



NASA

The PowerPoint presentations, provided as a supplement to the student texts from which they were derived, are always offered in a pdf format for those teachers who do not have the Microsoft® PowerPoint application.

Because teacher use of the presentation slide notes as talking points is vital for complete understanding of the concepts, the slide notes from the PowerPoint are provided here for those teachers using the pdf presentation. Therefore it is important to read and print out these talking points before presenting the material to your students. You may wish to use the teacher guide that accompanies this presentation for additional tips, delivery strategies, and correlation to the national standards.

### SLIDE NOTES/TALKING POINTS

Slide 1: This PowerPoint presentation can be used in conjunction with the “It Began with Apollo” student text in *Dynamic Design: A Collection Process.*

The information used to make this PowerPoint was taken from Journal Entries of all Apollo missions located at http://www.hq.nasa.gov/office/pao/History/alsj/a11/a11.step.html#1100253.

This presentation was put together to allow a class to read dramatically.

Slide 2: Narrator: This story is about the difficulties that astronauts experienced in using the solar wind collection device on the moon in the early 1970s. The first Apollo mission in which solar wind particles were collected was Apollo 11, the first mission in which humans landed on the moon.

Slide 3: Narrator: The following is the conversation that occurred during the Apollo 11 deployment of the solar wind collector. The speakers are astronaut Buzz Aldrin, Mission Control Capsule Communicator Bruce McCandless, and astronaut Neil Armstrong.

Slide 4: In every Apollo mission, the solar wind experiment was intentionally conducted in a consistent fashion. The telescopic pole was extended and the five sections locked automatically. The reel was then pulled out, and the foil was unrolled and fastened to a hook near the lower end of the pole. The pole was planted upright into the ground, but it did not necessarily have to be at a perfect angle with the moon’s surface.

It was important that the correct side of the foil was facing the sun. One side of the foil, marked with the word “SUN,” was pointed at the sun.

Buzz Aldrin deployed the solar wind experiment on July 21, 1969 UT.

Slide 5: Capsule Communications (CAP COM) is the one station at mission control that communicates information from mission control to the spacecraft. The CAP COM officer is usually an astronaut.

Why do you think NASA wants an astronaut at this station?

Slide 6: This is a photo that Neil Armstrong took of Buzz Aldrin with the solar wind experiment.

Where is the sun's light coming from in this picture? How were you able to determine this? The solar wind experiment is located to the right of astronaut Buzz Aldrin. From this picture, describe the size of the solar wind collector foil.

Slide 7: Teachers Note: During the time that this is read, you may have the person reading Aldrin's part use a broom stick to model this. Use a lamp with about a 60 watt bulb, darken the room and have the person playing Aldrin's part use the shadow to make a 90 degree angle.

Slide 8: As the experiment was being deployed, what do you think Bruce McCandless did? Do you think he had a checklist or was writing down what happened?

Slide 9: This is the first time this experiment was ever conducted on the moon. So the scientists that planned this did not know how hard the surface of the moon was.

What do you think would have happened if Aldrin could not have put the pole into the surface?

Knowing about the conditions of the moon, why was it not a problem for the pole to be stable in the ground?

Slide 10: The Apollo 11 solar wind collection (SWC) was developed for 18 hours and 42 minutes. Each subsequent Apollo mission, except 13 and 17, had increasingly longer exposure times.

Slide 11: Relate an analogy to students of a retractable window shade or overhead projector screen. Ask students if they have ever had trouble operating something like this. Another analogy is how difficult it is sometimes to roll up plastic kitchen wrap after it has been used.

Slide 12: The difficulty in rolling up the foil after collection varied from one mission to another. Apollo 12 astronaut Alan Bean had a tougher time rolling up the foil from that mission's SWC than Buzz Aldrin did in Apollo 11. Astronauts Alan Bean and Pete Conrad are speaking with mission control's Ed Gibson.

Slide 13-Slide 23: None

Slide 24: This is probably where Al is compressing the roll with his hands to get it tight enough to fit into the bag.

Slide 25: None

Slide 26: The experimenters are looking for relative abundances of isotopes of helium, argon, and neon, the chemically inert noble gases in the solar wind.

What do all inert or noble gases have in common?

Slide 27-Slide 29: None

Slide 30: Bean and Conrad could not get the foil to roll up automatically. They finally used their hands to roll it, and as a result the foil was soiled by the dirt adhering to the astronaut's gloves. After it was rolled, they discovered that it was too big to fit into the container that was used to return it, and had to crush it with their hands.

Slide 31: On subsequent Apollo missions the retrieval of the SWC had varying degrees of success.

Although there were no design changes for the retrieval of the experiment, the Apollo 16 foil was made of platinum and aluminum so that it could be cleaned with hydrofluoric acid to remove dust.

Suppose you were an engineer and heard Alan Bean's recommendation during his technical debrief. Describe the steps you would take to help remedy the problem of retrieving the SWC.

Slide 32: Observe the Apollo collector at left and the Genesis collector at right. Compare and contrast these two systems.

| **Apollo** | **Genesis** |
|---|---|
| - Deployed by humans. | - Deployed by machine. |
| - Collected only noble gasses. | - Collects elemental isotopes, atomic number 3-93. |
| - Simple design. | - More complex assembly. |

# Dynamic Design: A Collection Process

# Finding the Perfect Fit

## TEACHER GUIDE

### BACKGROUND INFORMATION

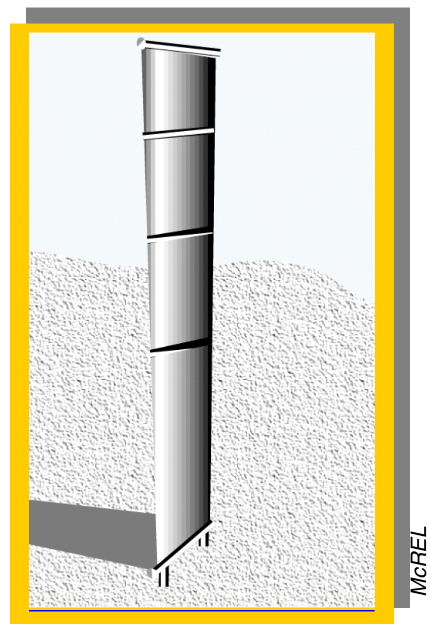
The sample return capsule (SRC) on the Genesis spacecraft contains wafers for collecting solar wind particles. The wafers are suspended over a frame. In this introductory activity students investigate different shapes that fit into a given space, which is the shape of the array frame that will be put into the canister in the sample return capsule. Students will experiment with different shapes to find the shape or combinations of shapes that cover the greatest background area. The greater the area that is covered, the more solar wind that will be collected.

### NATIONAL SCIENCE STANDARDS ADDRESSED

**Grades 5—8**
*Science and Technology*
Abilities of technological design.
*History and Nature of Science*
History of Science

**Grades 9—12**
*Science and Technolgy*
Abilities of technological design.

*(View a full text of the National Science Education Standards.)*



*Apollo-Type Solar Wind Collector Foil*

### NATIONAL MATH STANDARDS ADDRESSED

**Grades 5—8**
*Math Standard: Mathematics as problem solving*
Verify and interpret results with respect to the original problem situation.
*Math Standard: Number and Number Relationships*
Understand and apply ratios, proportions and percents in a wide variety of situations.
*Math Standard: Geometry*
Represent and solve problems using geometric models.
*Math Standard: Measurement*
Estimate, make, and use measurements to describe and compare phenomena

**Grades 9—12**
*Math Standard: Mathematics as problem solving*.
Apply the process of mathematical modeling to real-world problem situations.

*(View a full text of the National Math Education Standards.)*

### MATERIALS

For each group of students:

- Student Text, "It Began With Apollo"
- Student Text, "Shaping Up"
- Student Sheet, "Finding the Perfect Fit"
- Student Activity, "Finding the Perfect Fit"
- Shapes: 20 each of triangles, squares, trapezoids, parallelograms, and rhombi

Option 1: Teacher-made, dye-cut shapes
Option 2: Pattern blocks

- One Centimeter Graph paper
- Colored Pencils or Markers

OR
Option 3: TesselMania® software (see alternative strategies tip)

## PROCEDURE (Options 1 and 2)

1. Begin this session by having the students complete a Prereading Plan (PReP) that is described here. This strategy may be used to generate interest in content reading and assess levels of knowledge of the subject prior to reading the student text. First ask them for their *initial association with the concept.* Ask students to write the first thing that comes to mind when they hear the phrase "solar wind collection" on a piece of paper. If the students have not worked with the Genesis education module *Cosmic Chemistry: Sun and Solar Wind*, start with the phrase "solar wind." Once students have recorded their responses, move to the *reflections on initial association* phase. In this second step, list some of the responses from the initial association on the board and ask students, "What made you think of the response?" This will help students develop an awareness of their association. In the last section, *reformulation of knowledge,* the teacher should ask, "Based on our discussion and before we read the text, have you any new ideas about solar wind collection?" Through the use of PReP, teachers can assess which students have much, some, or little knowledge of the concept. Based on the class participation in this activity, the teacher should plan to either provide some background on solar wind or begin the design module by having students read the student text.

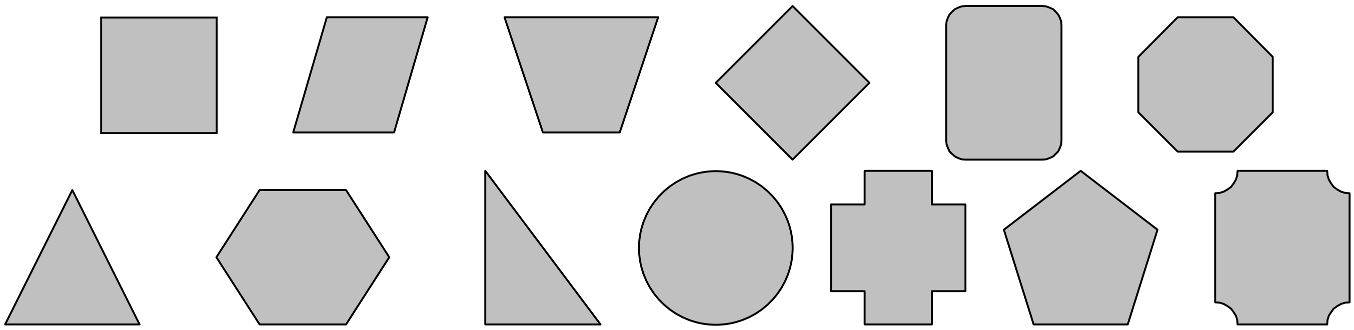
2. Explain to students that the first time solar wind particles were returned to Earth for study was during the Apollo missions. Ask students what they know about the Apollo missions from the early seventies. Explain that the solar wind experiments that were done during the Apollo missions provide a starting point for the Genesis solar collection mission. In other words, the fact that the solar wind experiments during Apollo were successful proved that the Genesis mission would be possible. Tell the students that an article about the Apollo solar wind experiments as a play can be read aloud in class.

3. Set the stage for this activity by having the students dramatically read the Student Text "It Began with Apollo." This text describes the Apollo mission experiments with Solar Wind Collectors (SWC). These lunar experiments represent the first time that solar wind particles were collected and returned to Earth for study. Students will read journal accounts from astronauts on the Apollo 11 and 12 missions. Assign students to read the different statements as in a play. There will be at least one narrator and one person each for astronaut: Buzz Aldrin, Mission Control Capsule Communicator Bruce McCandless, astronauts Alan Bean, Pete Conrad, and Mission Control Capsule Communicator Ed Gibson. Once the students have read the text, ask them to answer the questions about how the astronauts collected solar wind particles and to recommend design changes as they see fit. If students ask for help, refer them to the text. Answers for the first question may include the materials that the SWC was made from, how many sections there were, and what the various parts were. For question 2, students may suggest that extending the telescopic pole, unrolling the foil, and fastened to a hood near the bottom, the pole was planted into the ground with the correct side facing the sun. Retrieval was supposed to work like pulling up a window shade. Most missions had trouble with retrieval, although they were all successful. For question 3, answers will vary. Students may suggest that the tape be looked at, and perhaps design some tests that test the mechanism in the lunar-like environment. Other students may suggest including a larger bag in case this problem happens again.

4. Explain to the students that unlike the simple foil experiments that were completed on the Apollo mission, the Genesis mission will have five collector arrays, each consisting of a frame and solar wind collecting wafers. Explain that in this science module, they will study how the design affects a mission and discover some of the challenges associated with

collecting solar wind particles. Tell students that they will begin by studying how different shapes of solar wind collector wafers might fit into a frame.

5. Distribute Student Sheet, "Finding the Perfect Fit" to the student groups. Explain that the goal will be to use any shape or combination of shapes to fit the background frame.



6. Students will start by tracing the background frame onto a piece of graph paper and calculate the area using the counting squares method. Students count the number of squares inside the outline of the background frame.

7. Next students will fit the shapes into the background frame. They may choose as many different ways as possible. Students may use partial shapes to fill in gaps. When the group members have found an arrangement they think is best, they should trace the shapes onto the graph paper using colored pencils.

8. Using the method described in student activity sheet procedure 2, students should calculate the area of the background frame that they were able to cover. Students should also calculate the percent of the frame covered and the total number of covering pieces used. Percent of frame covered = (area covered by shades / total area of frame) X 100.

9. Each group's completed sheet can then be posted on the wall so other groups may review it. Tell groups to review the work done by other groups and to answer the questions as they complete this review. Discuss the following questions once students have completed them:
   1. a. Which shapes best fit into the background frame? Why? Question 1 answers will vary, students should reflect the fact they tried several shapes.
      b. What shapes do not fit well? Why not?
   2. What other shapes would you like to try? Why? Answers will vary.
   3. Would some shapes cost more than others to produce? Why or why not? Students may suggest that shape makes no difference; only the amount of material would change the cost. Others may explain that shapes that have more "corners" would cost more to cut.
   4. What factors beside cost should be considered when designing a collector wafer? Answers will vary. Some students may suggest that purity of materials is the most important for getting good results.
   5. Which of the above factors are most important? Which are least important? Why?

10. Students should read the Student Text "Shaping Up." This text has information about shapes found in nature. It begins with a short description of the honeycomb found in a beehive. Students are asked to think of other places in nature where hexagons occur. The benzene ring in organic chemistry is given as another example. The text concludes by describing the solar collector wafers and array that will be part of the sample return capsule on board the Genesis spacecraft.

11. Preview the next activity by telling students that two arrays will collect bulk solar wind. Ask them to brainstorm how the other arrays might be used to analyze specific regimes of solar wind, such as noble gas elements, oxygen, nitrogen, or alikali metals. This is what will be modeled in the next exploration activity.

> Alternate Strategies Tip
>
> This same activity can be adapted and completed by using a commercial or freeware software package on tessellation.

## REFERENCES

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http://www.beloit.edu/~biology/zdravko/voronoi.html
Shapes in Nature

http://www-sn.jsc.nasa.gov/explore/data/apollo/part1/swc.htm
Solar Wind Composition

http://www.hq.nasa.gov/office/pao/History/alsj/frame.html
Apollo Lunar Surface Journal

http://www-curator.jsc.nasa.gov/curator/genesis/Collectors.htm
JSC Contamination Control for Genesis

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The Access Indiana Teaching and Learning Center, M.C. Escher

GENESIS SEARCH FOR ORIGINS Education

# Finding the Perfect Fit

## Dynamic Design: A Collection Process

### STUDENT ACTIVITY

In this introductory activity you will investigate how different shapes will fit into a set background. The sample return capsule (SRC) on the Genesis spacecraft contains wafers for collecting solar wind particles. The wafers are suspended on a frame. In this activity the background represents the frame and the shapes represent the wafers. Your job will be to experiment with different shapes to find the shape or combinations of shapes that will cover the most area of the background frame.


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*The Payload Canister contains wafers that collect solar wind particles.*

**Procedure:**

1. Obtain a copy of the frame. Trace this pattern onto graph paper and count the number of squares that the frame encloses. Use the "half or more than half" rule for counting squares. (If half or more of the square is in the frame, count it; if there is less than half of the square in the frame, do not count it.) Record this area on your data sheet.

2. Obtain the materials from your teacher. Arrange the shapes in the frame so that they cover the greatest area. Once this is done, shade in the area that is not covered and calculate the area covered with the shapes. Repeat this procedure with different shapes in order to find the shape that covers the greatest area of the frame.

3. When you have found the arrangement that provides the greatest coverage, use colored pencils and trace the shapes onto the graph paper. Color the shapes so that your design will be easily seen. Calculate the area that you were able to cover with this final design. Calculate the percent of the frame area covered with each shape combination (percent covered by shape divided by area of frame). Count the number of pieces used. Post your completed frame. Compare your design with those of other groups, analyzing the area covered.

$$\text{Percent Area of Frame Covered} = \frac{\text{Area covered by shapes}}{\text{Total area of frame}} \times 100$$

**Table 1: Shapes that fit into the frame.**

Total Area of Frame

| Description of shapes used | Area covered by shapes | Percent of frame covered | Number of pieces used | Other factors to consider when using this design |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**Questions:**

1.a. What shapes best fit into the background frame?  Why?

1.b. What shapes do not fit well? Why not?

2. What other shapes would you like to try? Why?

3. Would some shapes cost more than others to produce? Why or why not?

4. What factors beside cost should be considered when designing a collector wafer?

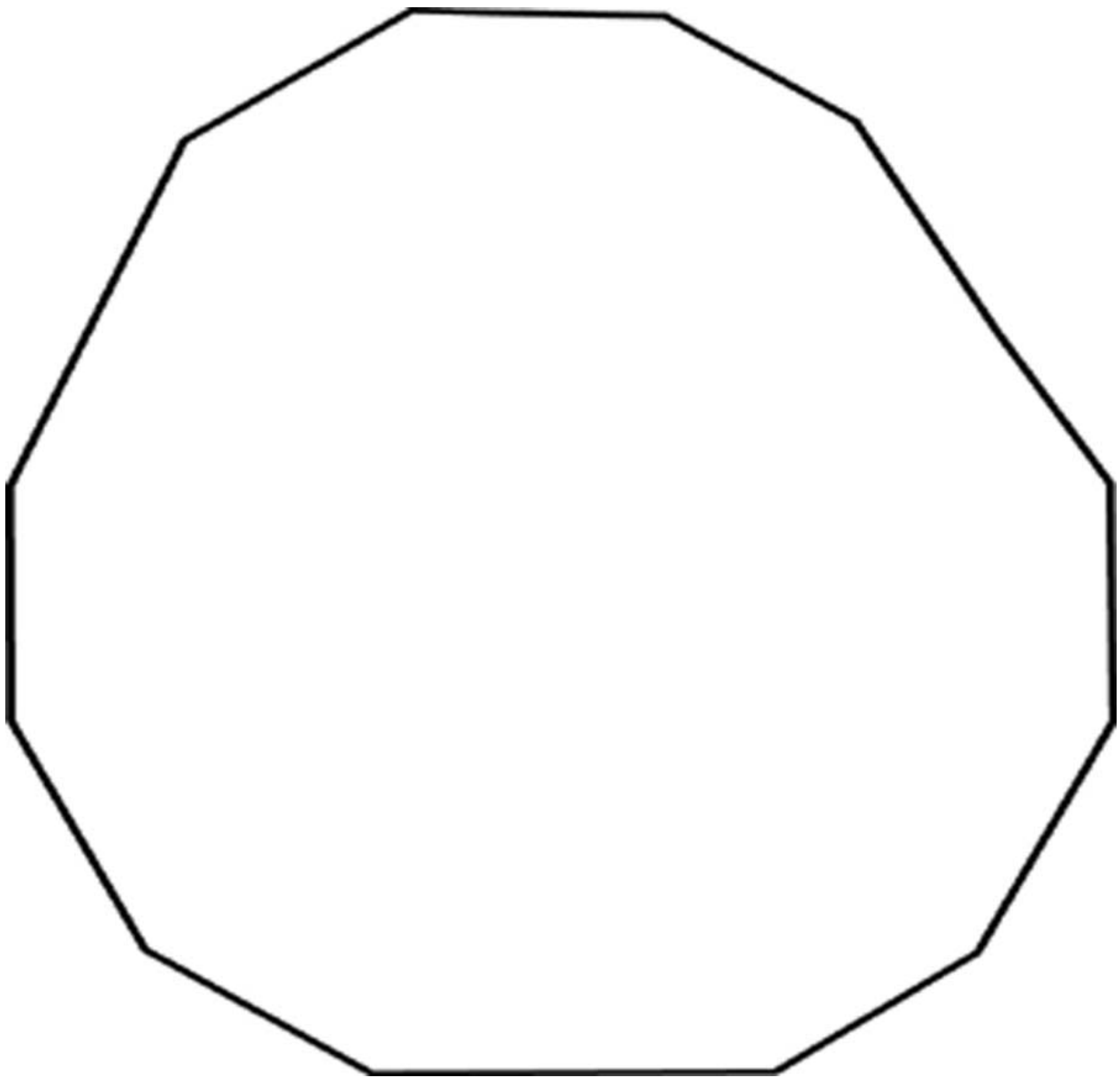
5. Which of the above factors are most important? Which are least important? Why?

# Dynamic Design: A Collection Process

## Finding the Perfect Fit

### STUDENT SHEET

The shape below is that of the Genesis Solar Collector Array Frame. Use the diagram below for the activity "Finding the Perfect Fit."

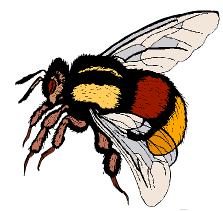


# Dynamic Design: A Collection Process

# Shaping Up

## STUDENT TEXT

**Bee's Wax**



What shape did your team use for the wafers? What shape do you think the Genesis scientists used? Would it surprise you to know that they chose the same shape that bees use to make their honeycomb? The central structure of a bee's colony is the wax comb. It is made up of six-sided white wax chambers or cells. Keep in mind that the honeycomb is made by instinct and completely in the dark. After eating honey, the worker bees rest. As they rest, their wax glands begin secreting wax scales. The glands are located in their abdomen. When the wax is secreted, it is in liquid form, but hardens quickly. The light yellow wax is then moved to the anterior portion of the bee's body to the mandibles. The mandibles form the wax into shape for making a comb. More and more wax is made until the cell is done. The walls of the cell are thin, but the outer edges are thick. Hutchins, in his book *Insects,* states that this strengthens the cells so that the bees are not injured when they walk about over them. "Mathematicians have determined that the shape of the cells is such as to hold the largest amount of honey with the smallest amount of structural material. One pound of wax will build about 35,000 cells which will hold about 22 pounds of honey. They are built precisely, there being less than three or four degrees of variation in their angles." (Hutchins, 1966) The cells vary in size according to their purpose.

Go to: http://www.beloit.edu/~biology/zdravko/honey_comb.jpg for a picture of a honeycomb.

**Shapes in Nature**

Have you determined what shape it is yet? If you guessed a hexagon, you are correct. A hexagon is an example of a regular polygon, one whose sides are all the same lengths and whose angles are all the same sizes. "Pentagons and hexagons are (the) most numerous (polygons) at high densities, with the hexagon shape as the perfect packing method." (Grant, 1968; Buckley and Buckley, 1977) Both honeycombs and most of the Genesis wafers are examples of a regular tessellation. A regular tessellation is one where the polygons are congruent, the vertices of at least three polygons meet at each vertex point, and there are at least three angles around each vertex point. (See Figure 1) Can you name some other hexagons or tessellations found in nature? One example of a hexagon in organic chemistry is the benzene ring molecule, $C_6H_6$. A benzene ring contains six carbon atoms attached together with a hydrogen atom attached to each carbon atom. (See Figure 2)

**Figure 1. Tessellation**

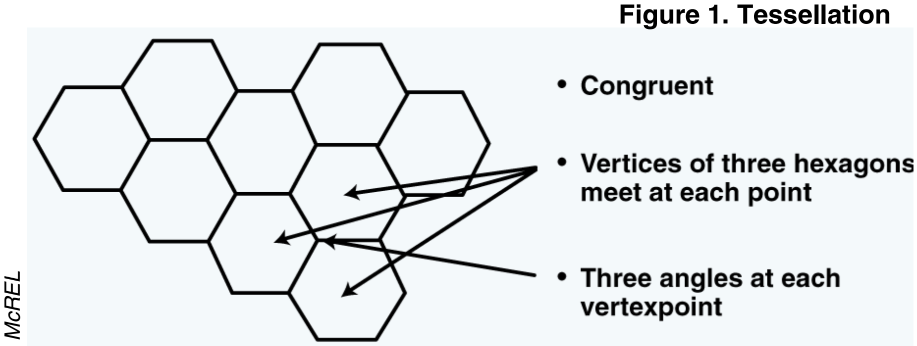
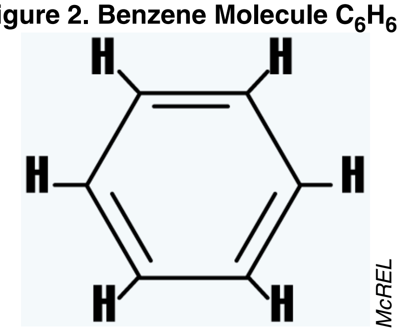


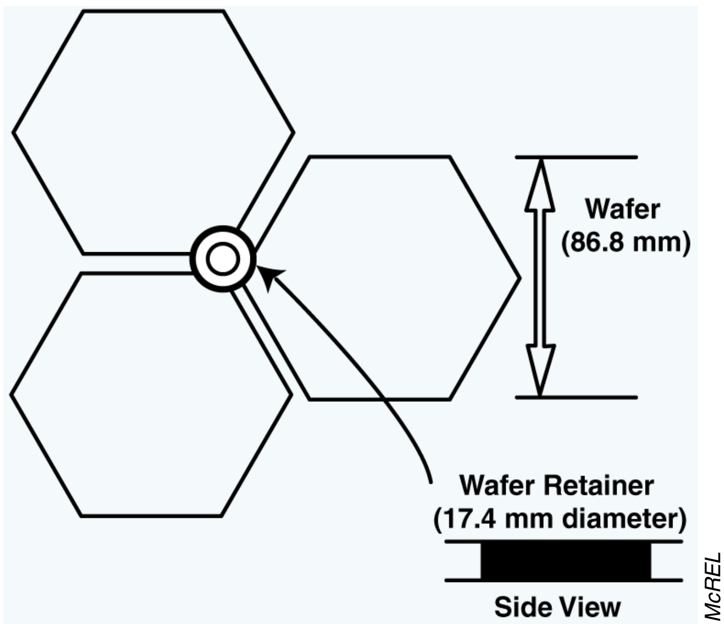

**Figure 2. Benzene Molecule $C_6H_6$**




*A carbon atom is at each corner of the hexagon.*

**Solar Wind Collector Wafers**
The solar wind collectors are constructed from wafers made of very pure, very clean materials attached to an array frame. Most of the wafers are hexagon-shaped, though some are half-hexagons near the edge of the array. Hexagon-shaped wafers maximize the collection area and so allow it to nest close to its neighbor in the array. Most of the wafers are made from silicon, though some are aluminum and gold, diamond, and germanium. The wafers will capture and hold the solar wind samples. During the two year "sun bath," every element from lithium to uranium are implanted. All wafer materials that are exposed to the solar wind will collect all solar wind elements. The science team chose the following variety of materials as collectors because each has advantages during analysis. Back on Earth, the silicon wafers, which are between 0.4 and 0.6 mm thick, will be used to analyze most of the elements and isotopes. Chemical vapor deposited diamond will be used to analyze oxygen, nitrogen, and other light elements. Aluminum will be used for the noble gases. Diamond, gold/platinum, germanium and other substances will be used for the alkali and radioactive elements. The wafers are installed and held together with a circular wafer retainer. (See Figure 3) A better explanation of wafer assembly will be detailed in upcoming Genesis module *Dynamic Design: A Clean Room*.

**Figure 3. Wafer and Retainer (not drawn to scale)**




**Collector Arrays**
There are five collector arrays that are 73 cm in diameter on the Genesis payload. Each array consists of 42 hexagon wafers and 13 incomplete hexagon wafers. The wafers are placed on the array so that there is one centimeter of space between them. There are four arrays stacked together in the container and one found on the lid. The lower stacked arrays are shaded from the solar wind when not in use. The top array and the one in the lid will be used to collect bulk solar wind (they will always be exposed). The bottom three in the stack will be used to collect specific regimes of solar wind. (See Figure 4)

**Figure 4. Collector Arrays in Canister**

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*Collector Array: Note there are four arrays stacked on the left and one in the lid at right. This shows the arrays collecting bulk solar wind using the array on the lid and the top array at left.*