
Sudekum Planetarium's

Lunar Odyssey



A Study Guide Produced
by the Staff of
Craigmont Planetarium

Lunar Odyssey

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LUNAR ODYSSEY
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Moon Literature

Jack and Jill

“Jack and Jill went up the hill
To fetch a pail of water.
Jack fell down and broke his crown
And Jill came tumbling after.”

The classic nursery rhyme of Jack and Jill originated from an ancient Norse myth that is really about the Moon and its phases. The story tells of a man named Mundilfari who had two incredibly beautiful and bright children. Because Mundilfari's children were so beautiful, he named girl Sun and the boy Moon. Naming the children such sacred names outraged the gods, so the children were kidnapped and taken up the heavens. In the heavens, the little girl was the true Sun's coachman, and the little boy guided the Moon's waxing and waning. After a while, the young boy saw two children on the Earth and decided to carry them off with him. The children's names were Bil and Hjuki, who were carrying water from a well. It is said that even unto this day, Bil and Hjuki can be seen on the face of the Moon. The significance of the children at the well with a pail of water is that the Moon was believed to influence the waters of the Earth and control rainfall.

Guarani Indian Legend

According to a legend from the Guarani Indians of South America, the Moon once lived on Earth with his two lovely daughters. One day, Moon saw a very beautiful child, and in order to “keep” the child, he stole its soul and hid it under a pot. Upon hearing this disturbing news, a shaman was sent to look for the child. The Moon asked his daughters not to give him away when the shaman came, but the clever shaman broke all of the pots anyway, and found the child's soul. The Moon was so ashamed, that he withdrew to the skies and took his daughters with him. Once in the heavens, the Moon entrusted his daughters with the task of lighting the way of souls, which we now know as the Milky Way.



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Moon Literature

Indian Moon Legend

In many cultures, the Moon is associated with death. The Upanishads, a sacred Indian text, preserves the idea that the Moon is a temporary resting place for the souls of the dead. The souls are said eventually to return to Earth in the form of rain. At the annual Pitcher Fourth festival, a legend of the Moon and a soul are told.

There was once a young, married woman with seven brothers. The day was that of the Pitcher Fourth festival, and all women were to fast to ensure the long lives and prosperity of their husbands. The young woman was fasting and growing very hungry, and her youngest brother took pity on her. The brother, wanting to help his sister, climbed into a tree and hung a lantern in it to fool his sister into thinking the Moon had already risen, and that her fast was over. The woman broke her fast, and immediately, her husband died. Until the next Pitcher Fourth festival, the woman watched over her husband's body and took care of it to prevent any decaying. When the next Pitcher Fourth festival arrived, she cut her finger and allowed some of her blood to flow into his mouth. The husband's soul returned from the Moon, and he returned to life at once!

The Pitcher Fourth festival is still a cultural element of today. Wives fast for a day, and when the Moon rises, each one finds an area where she can clearly see the Moon, and inscribes a sacred crossroads in the ground. And just as the wife in the legend, the women pour water into the inscribing as an offering to the Moon. The women then break their fast by first serving food to their husbands.

The Hottentots Legend

The Hottentots of South Africa tell a lively tale about the Moon. One day the Moon told a rabbit to go to Earth and tell the people that they would be reborn after death, just as the Moon is. The rabbit went to Earth. He got the message wrong and told them that they would only go around once in life. Upon hearing this, the Moon became furious and hit the rabbit with a stick, which is why the rabbit still has a split upper lip to this day, and people only go around once in life. The rabbit wanted revenge, so before he left the Moon, he hit it with his paws, and the marks are still clearly visible on the face of the Moon.

The Great Chief

According to the Siriono of Eastern Bolivia the Moon was a great chief that once lived on Earth. The chief was so great that he destroyed a race of evil people whom sprang from the reeds that the Siriono use to make their arrows. The great chief was named Yasi (Moon), and he had a child. One day, a Jaguar was playing rough with the child, and bit it too hard on the head. The young child died, and when Yasi heard of his child's death, he wanted some answers. Yasi wanted to know who murdered his precious child, but none of the animals would confess or tell. Yasi became so angry that he stretched the necks of the howler monkeys, put spines on the backs of porcupines, twisted the feet of the ant eaters, and threw the tortoise down so hard, that it could no longer walk fast. Yasi was still angry after this, so he decided to retreat to the sky a stay there as a great chief. Since the Moon is up there, he hunts often. When the Moon is dark, it means that he is hunting in distant places. The waxing of the Moon is when he returns from a hunt with a very dirty face. Each day, he washes his face a little until his face is clean again, and the Moon is full. As far as the waning Moon goes, he goes hunting and gets dirtier each day until his face is so dirty that it can no longer be seen, and we have a new Moon.

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Moon Poems



“There was an old woman tossed up in a basket
Seventy times as high as the Moon.
Where was she going? I couldn't but ask it,
For in her hand she carried a broom.
'Old woman,' quoth I, 'Oh whither so high?
'To sweep the cobwebs off the sky,' ”

“ The first time ever I saw your face,
I thought the Sun rose in your eyes
And the Moon and the stars
Where the gifts you gave
To the dark and the endless skies.”

—Ewan MacColl



“ But soft! What light through yonder window breaks?
It is the East, and Juliet is the Sun!
Arise, fair Sun, and kill the curious Moon,
Who is already sick and pale with grief,
That thou her maid art far more fair than she:
Be not her maid, since she is envious;
Her vestal livery is but sick and green,
And none but fools do wear it.”

—Shakespeare (Romeo and Juliet)



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Moon Poems

“The minstrels played their Christmas tune
To-night beneath my cottage eaves;
While smitten by a lofty Moon,
The encircling laurels, thick with leaves,
Gave back a rich and dazzling sheen
That overpowered their natural green.”
—Wordsworth, Christmas Minstrelsy



“Is the Moon tired?
She looks so pale
Within her misty veil;
She scales the sky from east to west,
And takes no rest.
Before the coming of the night
The Moon shows papery white;
Before the dawning of the day
She fades away.”
—Christina Rossetti, Is the Moon Tired?

“Softly, silently, now the Moon
Walks the night, in her silver shoon;
This way, and that, she peers, and sees
Silver fruit upon silver trees;
One by the casements catch
Her beams beneath the silvery thatch;
Couched in his kennel, like a log,
With paws of silver sleeps the dog;
From her shadowy cote the white breasts peep
Of doves in a silver-feathered sleep;
A harvest mouse goes scampering by,
With silver claws, and silver eye;
And moveless fish in the water gleam,
By silver reeds in a silver stream.”
—Walter de la Mare, Silver



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Moon Food

Moon Cakes from Shanghai

Please Note:

Adult supervision should always be used when using a hot stove, or oven.

These Chinese Moon Cakes are usually made in Chinese Moon Cake molds. The molds have the traditional imprint of chrysanthemums, and Chinese characters. Use the recipe below, and create your very own design on your Moon Cakes. Make sure you put your design on your Moon Cakes before placing them in the oven. Have fun making this tasty treat! The recipe makes about 16 cakes.

4 cups flour
4 tbsp. brown sugar
 $\frac{1}{2}$ tsp. salt
4 oz. margarine
1 egg
1 tsp. sesame oil

Filling:

2 tbsp. peanuts
2 tbsp. sesame seeds
2 tbsp. walnuts or pine nuts
2 tbsp. chestnuts, boiled until tender, or blanched almonds
2 tbsp. sultanas or other dried fruit, chopped
2 tbsp. chopped apricots
4 tbsp. brown sugar
2 tbsp. margarine
2 tbsp. rice flour, or poppy seeds



Preheat oven to 400°F. Sift flour, sugar, and salt together. Chop margarine into clumps, and mix with flour, sugar, and salt until crumbs form. Add enough hot water a little bit at a time to make a pastry dough (about half a cup). Cover with a cloth. Roast peanuts for about two minutes in very hot pan. Add sesame seeds, and cover to prevent nuts and seeds from jumping out of the pan. Continue to cook for another two minutes. Place peanuts and seeds in a food processor, and grind with the other nuts. Add the remaining filling ingredients, and mix together. Roll out pastry dough, and cut out rounds. Rub pastry mold with margarine. Press pastry on bottom and sides of mold. Put in a tablespoon of filling. Cover with another pastry round to make a lid. Wet edges to seal the top and bottom pastries together. Place each cake on a greased baking sheet. Beat eggs and sesame oil together, and brush each cake with this mixture. Bake about thirty minutes or until cakes are golden brown.

(Jack Santa Maria, Chinese Vegetarian Cookery, Rider and Co., London, 1983)

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Moon Food

Moon Biscuits



Please Note:
Adult supervision should always be used when
using a hot stove, or oven.

Moon biscuits are made in the shape of the crescent Moon. A whole hazelnut placed within them represent the Full Moon yet to come. Here is a fun and easy recipe.

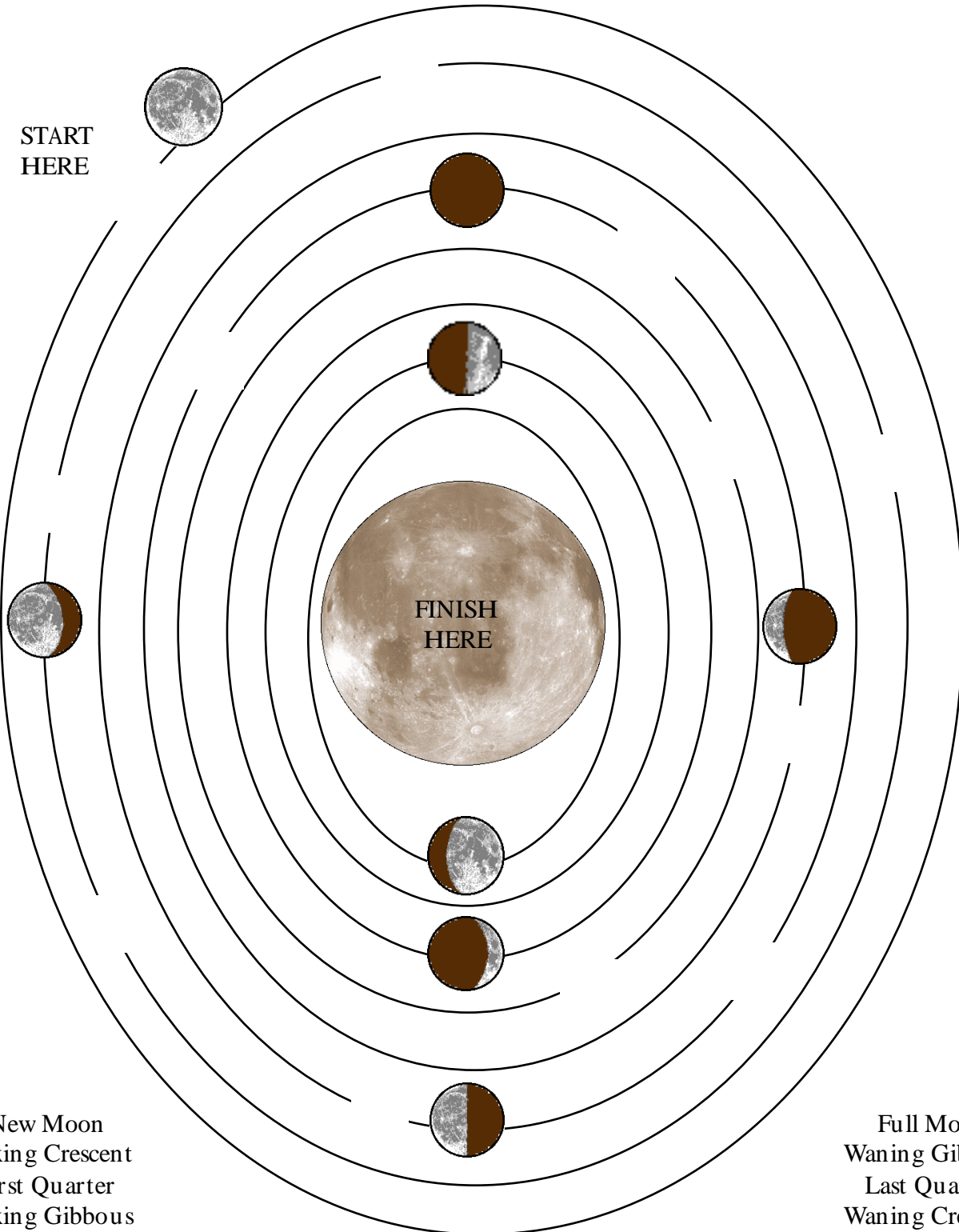
9 oz. whole wheat flour
3 oz. soft brown sugar
6 oz. butter or vegetable margarine
Large handful of hazelnuts

Preheat oven to 300°F. Blend sugar and butter. Add flour to form dough. Knead dough on floured surface. Gently work hazelnuts through the dough. Flatten the dough to about half an inch. With a Moon shaped pastry cutter cut out biscuits, place on baking sheet, and bake until light golden brown. Enjoy!

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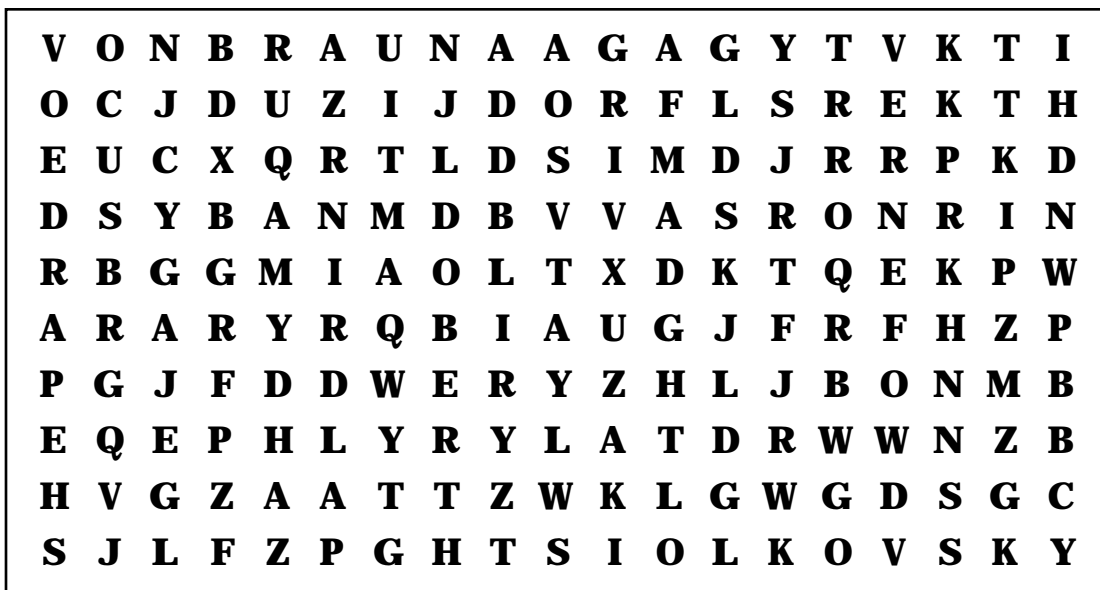
Eight Phase Moon Maze

Complete an entire Moon Phase Maze from Full Moon to Full Moon.
While on your journey select the correct phase name from the list below and label each phase.



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Wordsearch Puzzle



**GODDARD
ARMSTRONG
ALDRIN**

**SHEPARD
GAGARIN
OBERTH**

**VONBRAUN
TSIOLKOVSKY
VERNE**



Astronaut on the Moon!

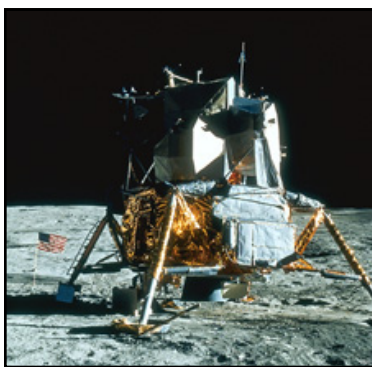
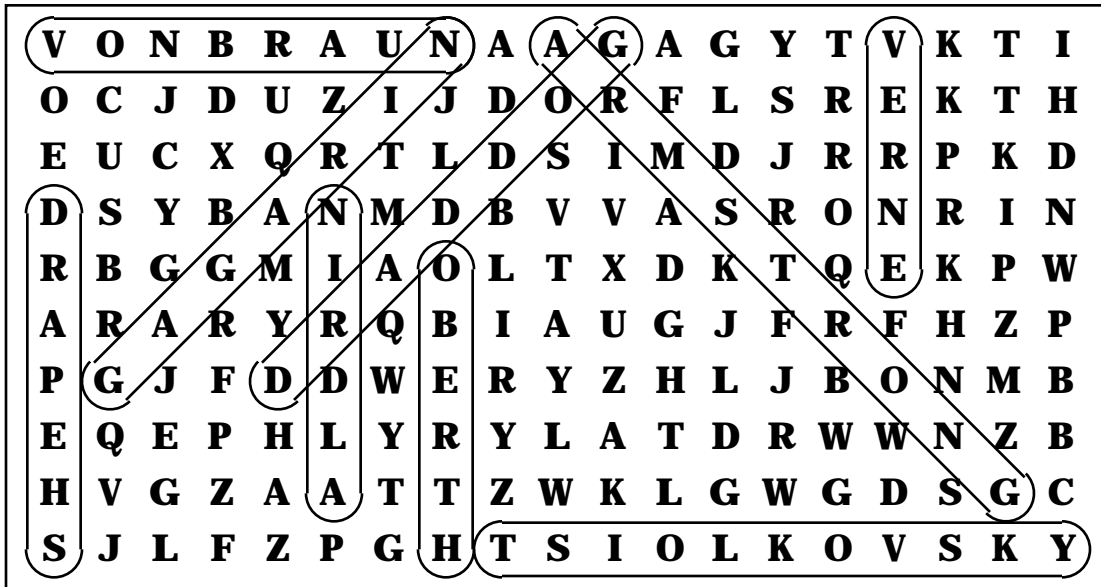
In the rectangle to the right, draw a picture of yourself on the Moon. Have fun, and be creative!



Me on the Moon!

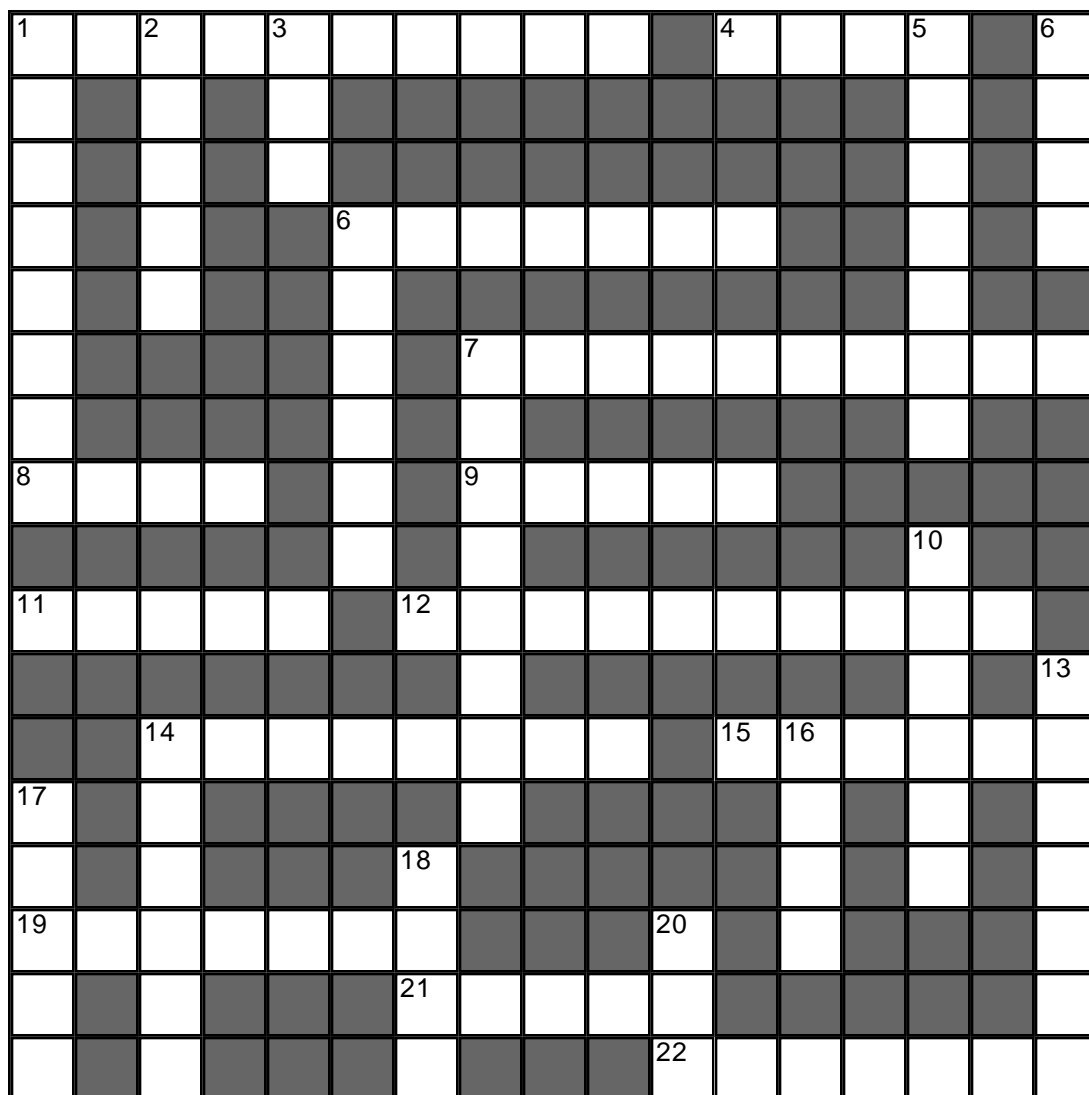
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Wordsearch Key



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Crossword Puzzle



Across

1. The study of the Moon
4. Center of rotation
6. Phase when Moon is half illuminated
7. Movement around a parent object
8. Edge of the Moon
9. Forces that distort another body
11. Icy object that orbits through a solar system
12. Air surrounding a planet or moon
14. Most orbit the Sun between Mars and Jupiter
15. Circular impact feature on a planet or moon
19. Type of rock with sharp-cornered bits
21. Channel or fissure on the Moon's surface
22. Moon origin theory in which one body broke apart

Down

1. Orbital period relative to the stars
2. Having to do with the Moon
3. Phase in which we can't see the Moon
5. Phase in which the Moon is fully illuminated
6. Quasi-stellar object
7. Spinning about an axis
10. Constellation name; same as a lunar feature
13. Movement by wind, water, ice, or gravity
14. Percent of reflectivity of a celestial body
16. Mass of tiny ice crystals
17. Path of one body around another
18. A lunar "sea"
20. The fourth, fifth, and sixth letters of the alphabet

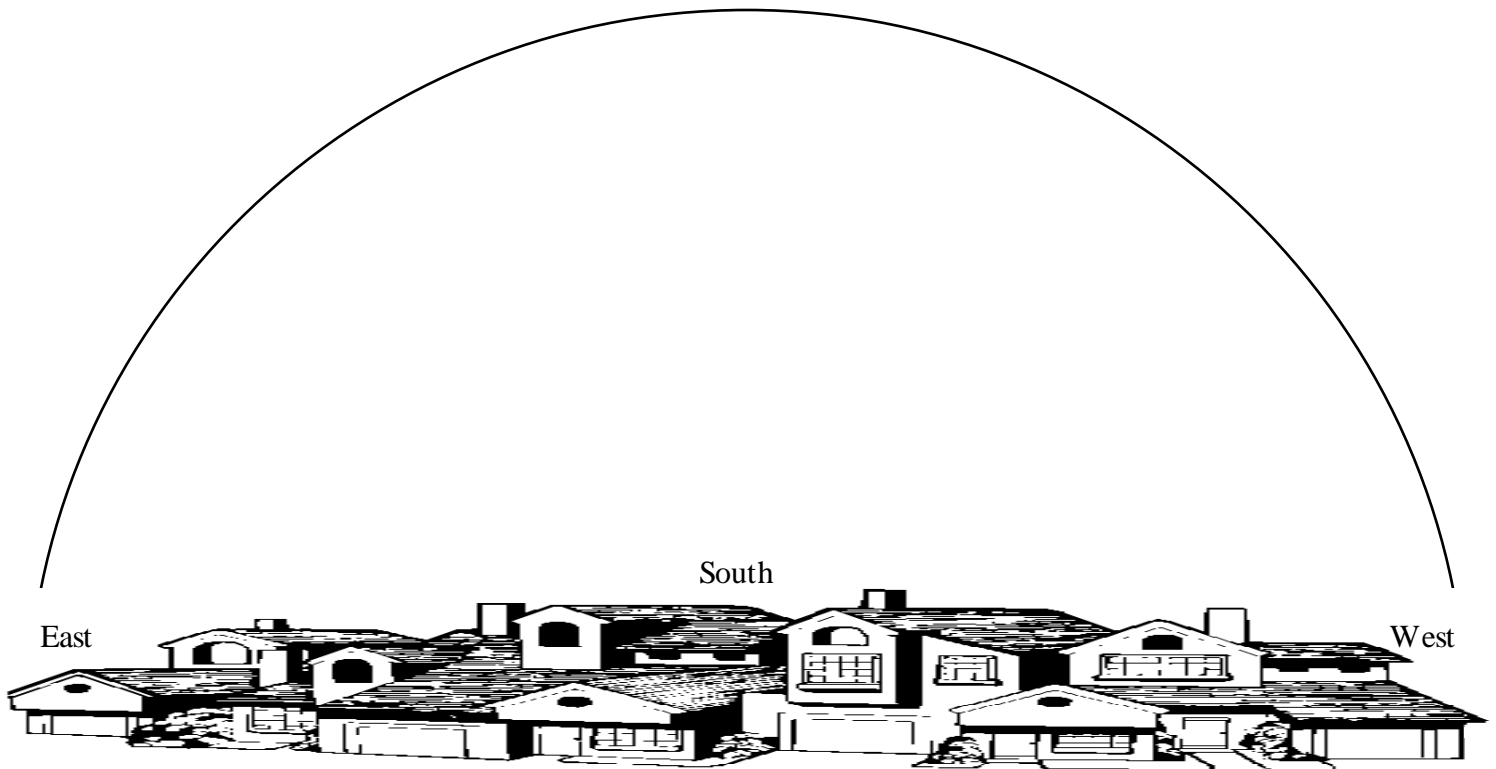
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Crossword Puzzle Solution

¹ S	E	² L	E	³ N	O	L	O	G	Y		⁴ A	X	I	⁵ S		⁶ F
I		U		E										Y		U
D		N		W										N		L
E		A			⁶ Q	U	A	R	T	E	R			O		L
R		R			U									D		
E					A		⁷ R	E	V	O	L	U	T	I	O	N
A					S		O							C		
⁸ L	I	M	B		A		⁹ T	I	D	A	L					
					R		A							¹⁰ C		
¹¹ C	O	M	E	T			¹² A	T	M	O	S	P	H	E	R	E
							I							A		¹³ E
		¹⁴ A	S	T	E	R	O	I	D		¹⁵ C	¹⁶ R	A	T	E	R
¹⁷ O		L					N					I		E		O
R		B				¹⁸ M						M		R		S
¹⁹ B	R	E	C	C	I	A				²⁰ D		E				I
I		D				²¹ R	I	L	L	E						O
T		O				E				²² F	I	S	S	I	O	N

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Observing the Moon's Motion



“The Moving Moon went up the sky, and nowhere did abide...” (William Shakespeare)

The Moon moves in our sky, and two different kinds of motion are involved. The Earth rotates on its axis every day. This movement makes the Moon rise above the eastern horizon, travel across the sky, and set below the western horizon. As the world turns, we can track the motion of the Moon during the day. The Moon also revolves around the Earth during the month. This motion makes the Moon appear in a slightly different place in the sky from night to night.

Observation One

Go outside some clear evening when the Moon is in the sky. Stand in one special spot, face south, and notice what object—your neighbor's house, a tree, a building, or whatever you choose—is directly in front of you. Instead of the neighborhood shown at the bottom of the diagram, draw the things you see on your own horizon.

Now draw the Moon as it appears in the sky, and note the time. Come back outside an hour later, stand in the same place, and face the same direction. Draw the Moon again. Repeat your observation one hour later. Can you estimate how far the Moon travels in an hour because of the rotation of the Earth on its axis? You can estimate degrees by holding out your fist at arm's length. One “fist” equals about 10° in the sky.

Observation Two

Select an observation spot, face south, and draw the objects on your horizon as you did previously. Draw the Moon, noting its position carefully with respect to the objects on your horizon. Write down the time of your observation.

The next night AT THE SAME TIME, repeat your observation. Repeat this procedure for four or five consecutive nights. Note how far the Moon travels from one night to the next. Use your “fist” to estimate how far the Moon travels in degrees.

Conclusion

If you've made careful measurements, you may find that the Moon moves about 15° per hour due to the Earth's rotation on its axis, and it moves about 13.2 degrees per day due to its revolution around the Earth.

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What is a Month?

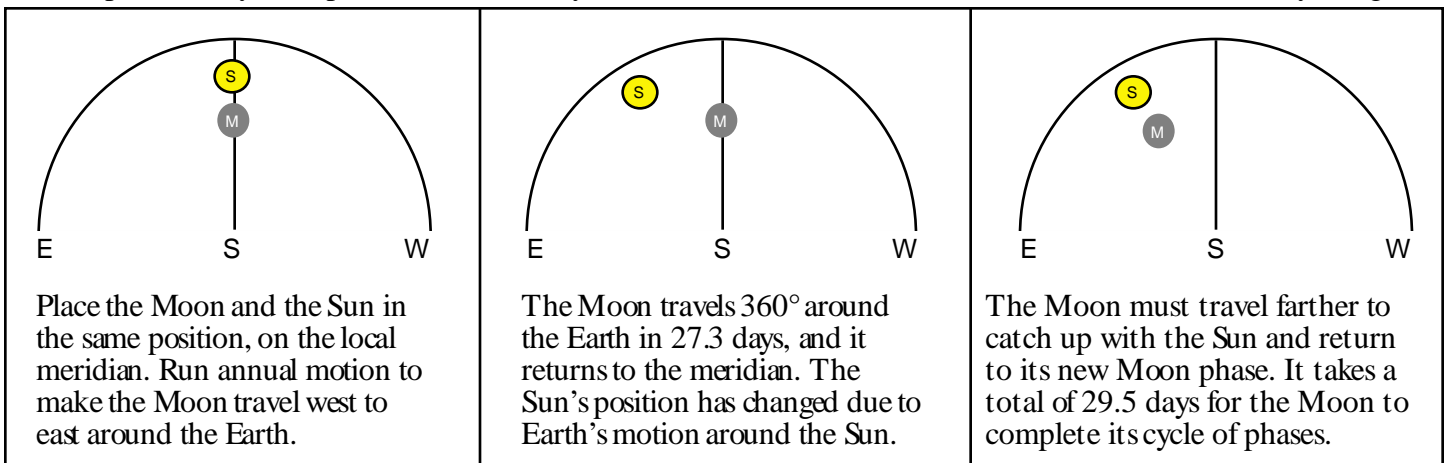
Scientists often rely on the movements of celestial bodies to define units of time. What is a month, for example? There are two ways to measure a month based on the motion of the Moon: the sidereal month and the synodic month.

A sidereal (star) month is the length of time it takes the Moon to complete one orbit around the Earth. We can measure this length of time by using a distant star as a reference point and determining how long it takes the Moon to travel around the Earth and line with that star again. This works because stars, due to their great distances, are basically fixed in position relative to the Earth. This orbital period takes 27.3 days to complete.

The other measurement, the synodic month, is how long it takes the Moon to complete all of its phases. We can measure from one new Moon to the next new Moon. The (new) Moon starts out aligned with the Sun, orbits around the Earth, and then catches up to the Sun again. This takes 29.5 days and is determined by the grouping (synod = group) the Moon with the Sun instead of a distant star.

To demonstrate these concepts in a planetarium, just follow these easy steps:

1. Use your local meridian as a reference point, or start/finish line, to substitute for a distant star.
2. Line up the Moon and the Sun along the meridian with either their leading or trailing limb touching the meridian or with the two bodies straddling the meridian as in the figures below this text.
3. To ensure that your audience can see the Moon at all times, set and lock the Moon in its full phase. Explain, however, that the Moon's phase in this position would be a new Moon. We're keeping it full for convenience.
4. Using annual motion, start the Moon through its revolution around the Earth. Stop annual motion when the Moon's leading or trailing edge (whichever you used first) is touching (or straddling) the meridian again.
5. Point out that while the Moon has now traveled 360° around the Earth and returned to its original position, it has not yet caught up with the Sun. This is the sidereal month, which takes 27.3 days to complete.
6. Continue moving the Moon, with annual motion, until it lines up with the Sun again. Now the Moon has completed its cycle of phases. This is the synodic month, or traditional lunar month, and it's 29.5 days long.



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The Moon Illusion and “Lunatics”

The Moon Illusion

The Moon appears to be much larger when it is near the horizon than when it is seen higher in the sky. This phenomenon is referred to as the Moon illusion. We subconsciously compare the size of the Moon with objects that are familiar to us, like buildings. To prove that this is an illusion, take a small pea or your finger, hold it at arm's length, and cover the Moon. Then do the same thing when the Moon is higher in the sky; you'll see that it doesn't change sizes.



You might also compare the apparent size of the image of the Moon in the upper right corner of this page with the image of the Moon rising behind a city skyline at the bottom of the page. Does it appear larger when you compare it with objects on the ground?

Some astronomers don't agree with this explanation. Instead, they prefer to say the sky near the horizon appears to be farther away from the observer than does the sky overhead. Two objects the same size viewed against farther and closer backgrounds will appear to have different sizes. For an alternate explanation of this highly debated phenomenon, visit the “New Thoughts on Understanding the Moon Illusion” Web page at <http://www.GriffithObs.org/IPSMoonIllus.html>.

Lunatics

Being a lunatic isn't so bad. Luna is the Latin word for Moon. The term lunatic originated when people mistakenly believed that staring at the light of the full Moon for too long would rob you of your mental faculties. Some amateur astronomers affectionately refer to themselves as lunatics because they're “crazy” about observing our Moon.

The Association of Lunar and Planetary Observers has a site at <http://www.lpl.arizona.edu/alpo/>. On this site you can find out more than you ever wanted to know about the Moon.

The lunar area of the Web site includes transient phenomena, lunar topography, eclipses, and a lunar calendar for each month. The calendar indicates the passage of significant stars and planets by the Moon during the course of its orbit of Earth. There's a monthly Lunar Observer newsletter for students of the Moon. Back issues are available. Sketches of lunar observers show features on the surface of the Moon.

If you thought the Moon was just a grey-white orb with a few dark spots on it, think again. Once you start studying the Moon, you'll be able to recognize its features like you would the face of an old friend.

Remember as you take a look at the nighttime sky to think about all the amazing magic the Moon can perform. And the next time that someone calls you a lunatic, be sure to say, “Thank you!”



Lunar Odyssey

“Why does the Moon Follow me?”

The Parallax Phenomenon

Have you noticed, when you're in a car, that objects close to you seem to pass by you as the car travels down the street, but the Moon seems to follow you? Try this experiment to understand why.





Hold your thumb out at arm's length. Close one eye, and use your thumb to cover up some object in the room. You might select a doorknob or a light switch. In the illustrations below, the thumb is covering up a distant star. Now close the eye that was open, and open the eye that was closed. What happened? Did your thumb seem to move? Why?

Your thumb jumped off the object it was covering because you observed it from a different location—from the other side of your head! When you observed from your other eye, the angle at which you were observing changed, so your thumb seemed to jump with respect to the object that was farther away.

Now repeat the experiment with your thumb only a foot away from your face instead of at arm's length. Did your thumb jump the same amount? With your thumb closer to your face, it appears to jump more than it did when it was farther away. This phenomenon is called parallax. Objects close to you seem to move a greater amount when you observe them from different angles. Objects farther away move less.

The Moon is 239,000 miles away from you. Can you see why it seems not to change position as you drive down the street while buildings, trees, and people move past you?

For another experience with parallax, try shooting free throws with one eye closed. The Parallax Phenomenon helps you judge distances because you have “stereo” vision and two images in your brain.

<p>1</p>  <p>Hold your thumb far away. Close one eye, and use your thumb to cover up some object in the room.</p>	<p>3</p>  <p>Now repeat the experiment with your thumb only a foot away from your face instead of at arm's length.</p>
<p>2</p>  <p>Now close the eye that was open, and open the eye that was closed. What happened?</p>	<p>4</p>  <p>Did your thumb jump the same amount?</p>

Lunar Odyssey

“Once in a Blue Moon” and other Lunar Phenomena



Above: This photograph was taken by the Clementine spacecraft. Courtesy of NASA.

We're all guilty of being lunatics, crazy about the Moon. The nighttime sky is never complete without a glimpse of the Moon. Our Moon provides us with light at night whenever it is above the horizon, and it controls the tides on Earth. Our partner in space, however, is involved in many more unusual phenomena than just the obvious ones.

The popular phrase “once in a blue Moon” has more validity than its connotation; there truly are “blue” Moons. A blue Moon occurs whenever there are two full Moons within the span of a single calendar month. On March 2nd, 1999 there was a full Moon, and there was another full Moon on March 31st. Adding to the excitement was that January 1999 was also a blue Moon month with full Moons on the 1st and the 31st as well. February 1999 was a month that had no full Moon at all.

Check with your local planetarium to find out

whether there are any more “blue Moon” months for the remainder of the year.

Blue Moons are not the only interesting phenomena associated with the Moon. People often see a ring of light, or a halo, around the Moon. These halos were believed to predict an oncoming rain shower. Halos, however, are not truly rain detectors; they simply indicate the presence of high thin ice clouds between us and the Moon. The halo is caused by the refraction of light through the thin clouds. The halo is comparable to a rainbow, except that in the sky there is no horizon to cut the ring in half. It makes a complete circle around the Moon.

If you see a halo around the Moon, count the number of stars inside the halo, and notice whether it rains within that number of hours. You'll be doing scientific observation and testing the hypothesis that a halo around the Moon means it's going to rain. Record your results and report them in class.

January 1999						
Sun	Mon	Tues	Wed	Thur	Fri	Sat
					1 ○	2
3	4	5	6	7	8	9 ☾
10	11	12	13	14	15	16
17 ●	18	19	20	21	22	23
24 ☽	25	26	27	28	29	30
31 ○						

In January of 1999, the Moon's phase was full on Friday the 1st, last quarter on Saturday the 9th, new on Sunday the 17th, first quarter on Sunday the 24th, and full again on Sunday the 31st.

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The Science of Lunar and Solar Eclipses

Eclipses occur when one celestial body passes in front of another and hides it from view. The types we hear about most often are lunar eclipses and solar eclipses. Both types involve the Moon.

Lunar Eclipses

The Earth, illuminated by the Sun, casts a long, cone-shaped shadow in space. Light from the Sun is blocked within this cone, called the umbra. Since the Sun is so huge, encircling the shadow cone is an area of partial shadow called the penumbra.

A total lunar eclipse occurs when the Moon passes completely into the umbra. Some indirect light bent by the Earth's atmosphere reaches the Moon, and it turns a shade of red. If the air is clean, the shade of red will be light. If the air is dirty, the shade of red can be very dark.

If the Moon travels directly through the center of the umbra, it may be obscured for up to two hours. If it doesn't, the eclipse may be partial. How much of the Moon is dark and how long the event lasts depends on how much of the Earth's shadow covers the Moon.

Before the Moon enters the umbra during either a total or a partial eclipse, it is within the penumbra, and the surface starts to darken slightly. The portion of the Moon that enters the umbra will appear much darker. During a total lunar eclipse, the lunar disk is not completely dark; it is faintly illuminated with a red light.

The Moon looks mysterious and magical. Many people can enjoy observing a lunar eclipse. It's as completely safe to look at the Moon during a lunar eclipse as it is to look at the Moon at any other time.

Solar Eclipses

During a solar eclipse, the Moon passes between the Sun and the Earth. The Sun is 400 times larger than the Moon, but it's also 400 times farther away. So, by coincidence, the Moon appears to be the same size as the Sun as seen from the Earth's surface. The Moon's disc can completely cover the Sun, blocking it from view on Earth.

Total solar eclipses occur when the Moon's umbra reaches the surface of the Earth. The width of the penumbra shadow, or the area of partial eclipse on the surface of the

Earth, is about 4828 km, but the path of totality is only about 112 km wide.

The length of the Moon's umbra varies from 367,000 to 379,800 km during its elliptical orbit around the Earth. The distance between the Earth and the Moon varies from 357,300 to 407,100 km. At certain times, when the Moon passes between the Earth and the Sun, its shadow may not reach all the way to the Earth. At such times, an annular eclipse occurs. An annulus, or "little ring" of the sunlight from the solar disk appears around the dark disk of the Moon.

How Often do Eclipses Occur?

If Earth's orbit around the Sun were in the same plane as the Moon's orbit about Earth, two eclipses would occur during each lunar month. A total eclipse of the Moon would happen every time the Moon was full, and a total solar eclipse would take place every time the Moon was new. The two orbits, however, are tilted 5.2° with respect to each other.

Eclipses can only occur when the Moon is within a few degrees of either of two points, called nodes, where its orbit crosses that of the Earth. If the Moon is new at that time, we see a total solar eclipse. If the Moon is full, we will see a total lunar eclipse.

Periodically both the Sun and the Moon return to the same position relative to one of the nodes, with the result that eclipses recur at regular intervals. The time of this eclipse interval, called the saros, is a little more than 6585.3 days, or about 18 years.

The saros, known since the time of ancient Babylonia, corresponds almost exactly to 19 returns of the Sun to the same node, 242 returns of the Moon to the same node, and 223 lunar months. An eclipse that recurs after the saros will be a duplicate of the earlier eclipse. It will be visible 120° farther west on the Earth's surface because of the rotation of the Earth during the third of a day included in the interval.

During one saros about 70 eclipses take place, usually 29 lunar eclipses and 41 solar eclipses. During a given year of the saros cycle, the minimum number of eclipses that can occur is two. The maximum is seven. Average is four.

Lunar Odyssey

Observing Solar Eclipses Safely

How does one observe a solar eclipse? Never, never, NEVER look through an unshielded telescope aimed at the Sun. Looking directly at the Sun—even for a short time—is dangerous. Looking directly at the Sun—even a small part of it—can actually burn your eyes. When you look at the Sun, your eye lenses focus its intense light on the retina, a delicate layer of cells at the back of the eye that sends visual images to the brain. The retina doesn't feel pain. You don't know it's being burned. This lesson can be learned at the expense of the Italian scientist Galileo who did so and became blind. Today with our high-transmission telescopes, eye damage will occur within less than a second.

There's no shield generally available that will protect your eyes from the Sun's invisible ultraviolet rays.

- NOT dark sunglasses
- NOT ordinary light filters
- NOT exposed photographic film
- NOT welding goggles
- NOT a piece of smoked glass

Simple and Safe Methods for Observing a Solar Eclipse

Method 1: The Pinhole Projector

Find a big cardboard box (e.g. 12" x 12" x 21" or even larger) and cut a $\frac{1}{2}$ " hole in the upper part of one end. Tape a piece of aluminum foil over the hole. Then, poke a hole in the aluminum foil with a straight pin or a needle.

Tape a piece of white paper inside the box, opposite the end with the pin hole but remember to **STAND WITH YOUR BACK TO THE SUN**. Hold the box over your head with the pin hole facing toward the Sun. An image of the Sun will appear on the paper. For a larger image, use a longer box. (See Figure 1.)

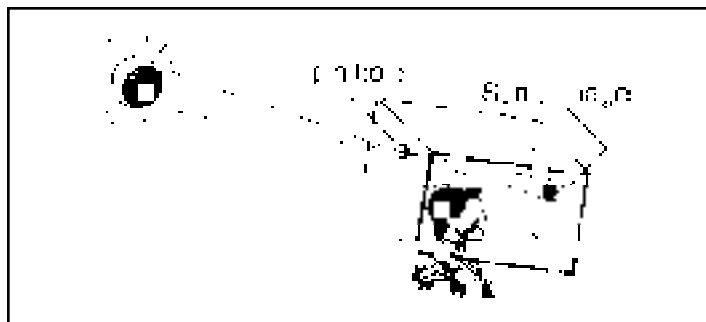


Figure 1: Here's a simple solar eclipse viewing box that's easy to make and will protect your eyesight.

Method 2: The Pinhole Mirror

A variation on the pinhole theme is the "pinhole mirror," nice for indoor classroom observing. Cover a pocket mirror with a piece of paper that has a $\frac{1}{4}$ " hole punched in it. Open a south-facing window, and place the covered mirror on the sunlit sill so it reflects a spot of light onto the far wall inside. The spot of light is an image of the Sun's face. The farther away the wall is, the better; the image will be only one inch across for every nine feet from the mirror.

Method 3: Projection through Binoculars or a Telescope

Hold a pair of binoculars up to the Sun. **DO NOT LOOK THROUGH THEM!** Allow the Sun to pass through them onto a wall or the ground. Or use a telescope to project an image of the Sun through its eyepiece onto a white piece of paper or a white poster board. The farther away the paper or poster board is, the larger the image of the Sun will be.

Method 4: Direct Observation

The only safe way to look at the Sun directly is through a specially designed Sun-observing filter made of Mylar™. Other materials, such as smoked glass, photographic filters, or layers of colored plastic, should never be used. Any filter used with a telescope or other optical instrument needs to go over the front, never the eyepiece. This keeps nearly all of the Sun's light and heat out of the instrument. Make sure the filter is secured firmly so it won't be dislodged by a gust of wind or the poke of a curious spectator's finger. Years ago cheap telescopes were sold with "Sun caps" meant to go over the eyepiece. This was a disastrous idea. They sometimes cracked under the Sun's heat, sending a sudden blaze of concentrated light into the observer's eye. If you have an eyepiece Sun filter, throw it out.

Lunar Odyssey

Biographies

ROBERT GODDARD was born in Massachusetts in 1882. He designed, built, and launched the world's first liquid fueled rocket.

NEIL ARMSTRONG was born in Ohio in 1930. In 1966 Neil was command pilot for the Gemini VIII mission. Then in July 1969 he was commander of the Apollo XI lunar mission. He was the first person to walk on the Moon.

EDWIN "BUZZ" ALDRIN was born in Montclair, New Jersey in 1930. He was the second human to stand on the Moon. Buzz walked in space during the Gemini XII mission before traveling in the lunar module for the Apollo XI landing.

ALAN SHEPHARD, JR. On May 5, 1961 Shepard became America's first astronaut launched into space in a Redstone rocket. He joined earlier cosmonauts from the Soviet Union. Shepard also led the crew of the Apollo XIV mission to the Moon and back.

YURI GAGARIN was born March 9, 1934 near Moscow, Russia. In 1961, Gagarin, a Russian cosmonaut, was the first person in space when he flew aboard the Vostok craft. His 1 hour 48 minutes flight orbited the Earth once.

HERMANN OBERTH was born in Germany in 1894. He wrote a book that showed how rockets could be used to launch objects into space. Oberth introduced the idea of stages. Once part of the rocket's fuel is expended (used up), that stage should be dropped as dead weight, so as not to slow down the spacecraft.

WERNHER VON BRAUN was born in Germany in 1912. Von Braun directed Germany's rocket development program in which he and his team built the V2 rockets used against England in World War II. The launch of the V2, which flew 120 miles, marked the beginning of the space age.

KONSTANTIN TSIOLKOVSKY was born September 17, 1857 at Izhevskoye, Russia. Tsiolkovsky wrote books which evolved from science fiction into scientific ideas and theories. He is considered the father of astronautics and rocket dynamics.

JULES VERNE was born February 8, 1828 on the Ile Feydeau in Nantes. Verne, a science fiction writer, wrote imaginative stories that dealt with various ways to travel in space and to the Moon.

Lunar Odyssey

Glossary of Terms

Albedo: the proportion of light falling on a surface that is reflected, expressed as a fraction or percentage

Asteroid: a fragment of material similar to planetary matter; most asteroids orbit the Sun between Mars and Jupiter

Atmosphere: the air surrounding a planet or moon and moving in currents around it

Axis: a real or imaginary line on which an object rotates or is regarded as rotating

Breccia: rock consisting of sharp-cornered bits or rock cemented together by sand, clay, or lime

Capture Theory: a theory on how the Moon was formed; the Moon was a separate body from the Earth that traveled around the Sun, and when it came too close to the Earth, the Earth's gravity captured the Moon

Catena: a chain of craters on a planetary surface

Coalesce: to unite or merge into a single body, group, or mass

Comet: an icy body orbiting in the solar system; it partially vaporizes when it nears the Sun, developing a diffuse envelope of dust and gas and, normally, one or more tails

Concentric rings: rings around a common center

Constellations: patterns made of stars; one of 88 designated areas in the sky or the pattern of stars within it

Crater: a circular feature on the surface of a planetary object

Dorsum: an irregular, wrinkled ridge feature found on planetary surfaces

Erosion: the movement of weathering products by wind, water, ice, or gravity

Fission Theory: a theory explaining the Moon's origin; it suggests that around four and a half billion years ago, when the Earth was still soft and molten and spun on its axis a lot faster, a chunk came off of the Earth; this chunk became the Moon

Fossa: a long, narrow, shallow depression on a planetary surface

Lunar Odyssey

Glossary of Terms

Gravity: the force that tends to draw all bodies in the Earth's sphere toward the center of the Earth

Gregorian Calendar: calendar built around the solar year and ignores the lunar cycle; most commonly used today

Islamic Calendar: 12 lunar months which form a cycle of 32 and a $\frac{1}{2}$ years relative to the solar year

Jewish Calendar: 12 lunar months that adds a thirteenth seven times in every 19 year cycle

Lunar eclipse: a phenomenon which occurs when the Moon crosses into the shadow of the Earth

Mare: literally meaning "sea," refers to extensive dark areas on the Moon

Meteors: also known as "shooting stars" or "falling stars;" brief luminous trails observed as particles of dust or pieces of rock from space enter the Earth's upper atmosphere and burn up because of friction

Mons: in describing planetary surfaces, a mountain

Nebula: a large cold mass of gas and dust

Observatory: a building equipped for scientific observation generally with a large telescope for astronomical research

Oceanus: literally meaning "sea;" biggest form of maria (plural form of mare)

Orbit: path followed by a body moving in a gravitational field

Palus: literally meaning "marsh" or "swamp;" a term used to name certain dark areas on the Moon

Planetesimal: a body of rock and/or ice (under 10 kilometers) formed in the primordial solar nebula

Planet: an astronomical body in orbit around a star, or the Sun, which has a mass too small to become a star

Planitia: a low plain found on the surface of the planet

Primordial: existing from the beginning

Lunar Odyssey

Glossary of Terms

Promontorium: literally “promontory” or “cape;” term used to describes a few features on the Moon where a brighter area protrudes into a darker area

Proto Moon: beginning stage of Moon formation

Quasar: a small extragalactic object that is exceedingly luminous for its angular size and has a large redshift

Revolution: the moving of a body in a circular course about an external point

Rille: a channel or fissure in the Moon’s surface

Rimes: a white mass of tiny ice crystals formed on grass, leaves, etc. from atmospheric moisture

Rorschach Test: a test for the analysis of personality in which the person being tested tells what is suggested to him or her by a standard series of inkblot designs

Rotation: turning motion of an object on its axis

Selenologists: scientists who study the Moon

Sidereal Month: the orbital period, relative to the stars, of the Moon around the Earth = 27.32166 days

Sinus: literally meaning “bay;” used to describe certain features that have a bay-like appearance along the borders of the Moon

Space Race: the race between different countries, mainly the United States and the Soviet Union, to get to the Moon

Stars: twinkling points of light; distant suns like our Sun

Synodic Month: the time between successive new Moons = 29.53059 days

Tidal Force: the effect of the Moon’s gravitational pull on the Earth; any distorting gravitational force

Vallis: a curving valley on the surface of a planet

Lunar Odyssey

Overview of the Major Moons of our Solar System

Earth's Moon

Average distance from Earth: 384,000 km or 239,000 miles

Orbital period: 27 days, 7 hours, 44 minutes

Diameter: 3,476 km/2,160 miles Surface gravity: 0.16g

Composition: Basaltic (dark volcanic material) dust and rocks

Atmosphere: None

Surface temperature: Daytime can exceed 93°C (200°F); night temperature can drop to -129°C (-200°F)

Surface appearance: Battered by meteorites, comets and asteroids; covered with craters, dust and rock

Mars's Moon Phobos

Average distance from Mars: 9,400 km or 5,850 miles

Orbital period: 7 hours, 40 minutes

Diameter: 21 km/13 miles Gravity: 0.0008g

Composition: Basaltic (dark volcanic material) rocks

Atmosphere: None

Surface temperature: -100°C (-148°F) on sunlight side, -150°C (-238°F) on night side

Surface appearance: Entirely covered with craters and rock

Mars's Moon Deimos

Average distance from Mars: 23,500 km or 14,600 miles

Orbital period: 1 day, 6 hours, 19 minutes

Diameter: 12 km/7.3 miles Gravity: 0.0003g

Composition: Basaltic (dark volcanic material) rocks

Atmosphere: None

Surface temperature: -100°C (-148°F) on sunlight side, -150°C (-238°F) on night side

Surface appearance: Entirely covered with craters and rock

Lunar Odyssey

Overview of the Major Moons of our Solar System

Jupiter's Moon Io

Average distance from Jupiter: 422,000 km or 262,000 miles

Orbital period: 1 day, 18 hours, 28 minutes

Diameter: 3,630 km/2,250 miles Gravity: 0.188g

Composition: Basaltic (dark volcanic material) rocks and dust

Atmosphere: None

Surface temperature: -150°C (-238°F) on sunlight side, -190°C (-310°F) on night side

Surface appearance: Craters, rock; known to have active volcanoes releasing sulfur onto surface

Jupiter's Moon Europa

Average distance from Jupiter: 671,000 km or 417,000 miles

Orbital period: 3 days, 13 hours, 13 minutes

Diameter: 3,140 km/1,950 miles Gravity: 0.137g

Composition: Water ice and carbon dioxide ice

Atmosphere: None

Surface temperature: -150°C (-238°F) on sunlight side, -190°C (-310°F) on night side

Surface appearance: Entirely covered with ice, possibly an ocean layer under the ice

Jupiter's Moon Ganymede

Average distance from Jupiter: 1,070,000,000 km or 665,000 miles

Orbital period: 7 days, 3 hours, 43 minutes

Diameter: 5,260 km/3,270 miles Gravity: 0.15g

Composition: Basaltic (dark volcanic material) rocks and ice

Atmosphere: None

Surface temperature: -150°C (-238°F) on sunlight side, -190°C (-310°F) on night side

Surface appearance: Entirely covered with craters and rock

Jupiter's Moon Callisto

Average distance from Jupiter: 1,885,000 km or 1,170,000 miles

Orbital period: 16 days, 16 hours, 32 minutes

Diameter: 4,800 km/2,930 miles Gravity: 0.13g

Composition: Basaltic (dark volcanic material) rocks and ice

Atmosphere: None

Surface temperature: -150°C (-238°F) on sunlight side, -190°C (-310°F) on night side

Surface appearance: Entirely covered with craters and rock

Saturn's Moon Titan

Average distance from Saturn: 1,221,000 km or 759,000 miles

Orbital period: 15 days, 22 hours, 41 minutes

Diameter: 5,150 km/3,200 miles Gravity: 0.141g

Composition: rock and ice

Atmosphere: Extensive nitrogen atmosphere with a surface pressure 1.6 times that of Earth. Atmosphere is colored orange by a smog of organic material

Surface temperature: -320°C (-544°F)

Surface appearance: Uncertain; possibly methane oceans, ice, and rock

Lunar Odyssey

Overview of the Major Moons of our Solar System

Uranus's Moon Miranda

Average distance from Uranus: 129,900 km or 80,700 miles.

Orbital period: 1 day, 9 hours, 55 minutes.

Diameter: 485 km/300 miles. Gravity: 0.0089g

Composition: Rock and ice.

Surface temperature: -195°C (-320°F).

Surface appearance: One of the most varied surfaces, with features including mountains, craters, and giant cliffs.

Neptune's Moon Triton

Average distance from Neptune: 354,000 km or 220,000 miles.

Orbital period: 5 days, 21 hours, 3 minutes.

Diameter: 2,720 km/1,690 miles. Gravity: Uncertain.

Composition: Rock and ice.

Surface temperature: -200°C (-340°F).

Surface appearance: Many craters and bright patches of ice. A few geysers of nitrogen gas.

Pluto's Moon Charon

Average distance from Pluto: 19,100 km or 12,000 miles.

Orbital period: 6 days, 9 hours, 17 minutes.

Diameter: 1,285 km/800 miles. Gravity: Uncertain.

Composition: Probably ice and rock.

Lunar Odyssey

Lunar Exploration Timeline

January 2, 1959

Luna 1, the first spacecraft to reach the Moon and the first of a Soviet automatic interplanetary station series, found out that there was not a magnetic field on the Moon and that there was a solar wind through interplanetary space.

March 4, 1959

Pioneer 4, an American spacecraft, passed by the Moon and detected no lunar radiation.

September 12, 1959

Luna 2, the second of the Soviet automatic interplanetary station series and the first spacecraft to land on the Moon, confirmed that there was not a magnetic field on the Moon and found no trace of radiation belts.

October 4, 1959

Luna 3, the third of the Soviet automatic interplanetary station series, was the first spacecraft to return images of the Moon's farside.

August 23, 1961

Ranger 1, an American spacecraft, had the mission to test the performance of the functions and parts that are needed to run subsequent lunar and planetary missions using essentially the same design. It was also intended to study the nature of fields and particles in interplanetary space. Ranger 1 did enter into orbit around the Earth, but it did not leave the orbit as planned.

November 18, 1961

Ranger 2, an American spacecraft, was intended to do a flight test of the Ranger spacecraft system designed for future lunar and interplanetary missions. Ranger 2 became stranded in low Earth orbit because the roll gyro would not start. The orbit decayed and the spacecraft reentered the Earth's atmosphere.

January 26, 1962

Ranger 3, an American spacecraft, had the mission to transmit pictures of the lunar surface to Earth 10 minutes prior to landing on the Moon. The goals of this spacecraft were to collect gamma-ray data, to study radar reflectivity of the lunar surface, and to continue testing the Ranger program. It would land a capsule on the Moon. A malfunction resulted in excessive speed, and reversed signals broke contact with the Earth causing the spacecraft to pass by the Moon and jump into orbit with the Sun.

April 23, 1962

Ranger 4, an American spacecraft, had basically the same goals as Ranger 3. Like Ranger 3, this spacecraft had problems. The computer and sequencer did not provide signals for the solar panels or the operation of the Sun and Earth acquisition system. Ranger 4 crashed onto the Moon.

Lunar Odyssey

Lunar Exploration Timeline

October 18, 1962

Ranger 5, an American spacecraft, had the same goals as Rangers 3 and 4. A malfunction in the booster system resulted in excessive speed and reverse signals resulted in loss of contact from the Earth. Ranger 5 passed by the Moon and moved into the Sun's orbit.

April 2, 1963

Luna 4, the fourth of the Soviet automatic interplanetary station series, was the first successful spacecraft of the USSR's second generation lunar program. This spacecraft was first placed in the Earth's orbit and then launched towards the Moon. It did not succeed.

January 30, 1964

Ranger 6, an American spacecraft, was designed to take high-resolution, closeup TV pictures of the lunar surface before it impacted on the Moon. Midcourse trajectory correction was established in this mission. No pictures were taken because of a problem with the TV power system turning on during separation.

July 28, 1964

Ranger 7, an American spacecraft, was intended to achieve a lunar impact trajectory and to take high-resolution pictures of the lunar surface in the final minutes before impact. Ranger 7 took excellent pictures starting at 17 minutes prior to impact. It was a successful mission.

February 17, 1965

Ranger 8, an American spacecraft, was intended to achieve a lunar impact trajectory and to take high-resolution pictures of the lunar surface in the final minutes before impact. Ranger 8 began taking pictures 23 minutes prior to impact. This mission was successful.

March 21, 1965

Ranger 9, an American spacecraft, was intended to achieve a lunar impact trajectory and to take high-resolution pictures of the lunar surface in the final minutes before impact. Ranger 9 began taking pictures 19 minutes prior to impact. Real time TV coverage with live network broadcasts of many images were provided for this flight.

May 9, 1965

Luna 5, the fifth of the Soviet automatic interplanetary station series, was designed to attempt a lunar soft landing, but did not make it due to a system failure which caused the spacecraft to crash on the lunar surface.

June 8, 1965

Luna 6, the sixth of the Soviet automatic interplanetary station series, was intended to travel to the Moon, but it ended up passing by the Moon.

Lunar Odyssey

Lunar Exploration Timeline

July 18, 1965

Zond 3, a Soviet spacecraft, took 25 pictures of good quality of the lunar farside covering 19,000,000 km of the lunar surface. Zond 3 also proved the ability of the communications system on the spacecraft.

October 4, 1965

Luna 7, the seventh of the Soviet automatic interplanetary station series, was intended to achieve a soft landing on the Moon's surface, but due to problems with the retro-rockets the spacecraft crashed on the lunar surface.

December 3, 1965

Luna 8, the eighth of the Soviet automatic interplanetary station series, was launched to try and achieve a soft landing on the Moon, but yet again the spacecraft crashed.

January 31, 1966

Luna 9, the ninth of the Soviet automatic interplanetary station series, achieved the first lunar soft landing and also provided a panoramic view of the lunar surface by returning three series of TV pictures.

March 31, 1966

Luna 10, the tenth of the Soviet automatic interplanetary station series, conducted gravitational studies dealing with the Moon.

May 30, 1966

Surveyor 1, the first American spacecraft to land safely on the Moon, returned pictures of the spacecraft footpad, surrounding lunar terrain, and surface materials. The spacecraft also returned data on radar reflectivity of the lunar surface, bearing strength of the surface, and spacecraft temperatures for the purpose of analyzing lunar temperatures.

August 10, 1966

Lunar Orbiter 1, an American spacecraft, was designed to take pictures of smooth areas to help find safe landing sites for the Surveyor and Apollo missions. It also collected selenodetic, radiation intensity, and micrometeoroid impact data. This spacecraft was tracked until it impacted the lunar surface on command.

August 24, 1966

Luna 11, the eleventh of the Soviet automatic interplanetary station series, entered a lunar orbit to research the following: 1, the Moon's chemical composition; 2, lunar gravitational anomalies; 3, concentration of meteorite streams; and 4, intensity of radiation. After a total of 127 radio transmissions and 277 orbits around the Moon, Luna 11's batteries failed.

October 22, 1966

Luna 12, the twelfth of the Soviet automatic interplanetary station series, took pictures of the lunar surface until its batteries died after 602 orbits around the Moon.

Lunar Odyssey

Lunar Exploration Timeline

November 6, 1966

Lunar Orbiter 2, an American spacecraft, was designed to take pictures of smooth areas to help find safe landing sites for the Surveyor and Apollo missions. It also collected selenodetic, radiation intensity, and micrometeoroid impact data. This spacecraft was tracked until it impacted the lunar surface on command.

December 21, 1966

Luna 13, the thirteenth of the Soviet automatic interplanetary station series, took panoramic pictures of the Moon from different Sun angles.

February 4, 1967

Lunar Orbiter 3, an American spacecraft, was designed to take pictures of smooth areas to help find safe landing sites for the Surveyor and Apollo missions. It also collected selenodetic, radiation intensity, and micrometeoroid impact data. This spacecraft was tracked until it impacted the lunar surface on command.

April 17, 1967

Surveyor 3, an American spacecraft, achieved a soft landing. It had the mission of determining various characteristics of the lunar terrain to help in preparation for the Apollo missions. Surveyor 3 provided much data on the strength, texture, and structure of lunar material.

May 8, 1967

Lunar Orbiter 4, an American spacecraft, was designed to take pictures of smooth areas to help find safe landing sites for the Surveyor and Apollo missions. It also collected selenodetic, radiation intensity, and micrometeoroid impact data. It was tracked until it crashed onto the lunar surface due to the natural decay of its orbit.

August 1, 1967

Lunar Orbiter 5, an American spacecraft, was designed to take pictures of smooth areas to help find safe landing sites for the Surveyor and Apollo missions. It also collected selenodetic, radiation intensity, and micrometeoroid impact data. This spacecraft was tracked until it impacted the lunar surface on command.

September 8, 1967

Surveyor 5, an American spacecraft, achieved a soft landing and had the mission to obtain postlanding TV pictures of the lunar surface, conduct a Vernier engine erosion experiment, determine the relative abundance of the chemical elements in lunar soil, obtain touchdown data, and obtain thermal and radar reflectivity data. Pictures were taken up to four days after landing.

November 7, 1967

Surveyor 6, an American spacecraft, achieved a soft landing and had the mission to obtain postlanding TV pictures of the lunar surface, conduct a Vernier engine erosion experiment, determine the relative abundance of the chemical elements in lunar soil, obtain touchdown data, and obtain thermal and radar reflectivity data. This spacecraft also performed so that it could move its location on the lunar surface.

Lunar Odyssey

Lunar Exploration Timeline

January 7, 1968

Surveyor 7, an American spacecraft, was the fifth and final spacecraft of the Surveyor series to achieve a soft landing. The goals of this mission were to 1, perform a soft landing; 2, obtain postlanding TV pictures; 3, determine the relative abundances of chemical elements; 4, manipulate lunar material; 5, obtain touchdown dynamics data; and 6, obtain thermal and radar reflectivity data.

April 7, 1968

Luna 14, the fourteenth of the Soviet automatic planetary station series, was the last flight of the second generation of the Luna series. Its purpose was to provide data for the studies of the interaction between lunar and Earth masses, the lunar gravitational field, the stability of radio communications at different positions, solar charged particles and cosmic rays, and the motion of the Moon.

September 15, 1968

Zond 5, a Soviet spacecraft, launched from Earth and flew to the Moon to make a few scientific probes during its flyby and headed back to Earth. On this mission high quality pictures were taken of the Earth.

November 10, 1968

Zond 6, a Soviet spacecraft, took pictures of the lunar near and farside with panchromatic film. This spacecraft had a controlled re-entry and landed in a predetermined region of the Soviet Union.

December 21, 1968

Apollo 8, an American spacecraft, was the first of the Apollo series to orbit the Moon successfully and the first manned spacecraft to leave Earth's gravity and reach the Moon. This mission provided operational experience and tested the Apollo command module systems which included communications, tracking, and life-support. It also allowed evaluation of a crew performance on a lunar orbiting mission. The crew took pictures of the lunar surface on the farside and nearside, obtained information on topography and landmarks, and other scientific data necessary for future Apollo landings.

May 18, 1969

Apollo 10, an American spacecraft, was the second Apollo mission to orbit the Moon and the first to travel to the Moon with the full Apollo spacecraft which included the Command Service Module 'Charlie Brown' and the Lunar Excursion Module 'Snoopy.' The objectives of this mission were to demonstrate crew, space vehicle, and mission support facilities during a manned lunar mission and to evaluate the Lunar Module performance in the lunar environment. The only thing that Apollo 10 did not do was land on the Moon.

July 13, 1969

Luna 15, the fifteenth of the Soviet automatic interplanetary station series, studied circumlunar space, the lunar gravitational field, and chemical composition of lunar rocks. Luna 15 crashed onto the lunar surface after 52 orbits around the Moon.

Lunar Odyssey

Lunar Exploration Timeline

July 16, 1969

Apollo 11, an American spacecraft, achieved its goal of being the first mission in which humans walked on the lunar surface and returned to Earth. While on the Moon, they set up scientific experiments, took pictures, and collected lunar samples.

August 7, 1969

Zond 7, a Soviet spacecraft launched from a mother spacecraft, to further studies of the Moon and circumlunar space, to obtain pictures of the Earth and Moon from different distances, and to flight test the spacecraft systems. Zond 7 completed its mission and achieved a soft landing in a preset region in the Soviet Union.

November 14, 1969

Apollo 12, an American spacecraft, was the second mission in which humans landed on the Moon and returned to Earth. Apollo put a lunar surface experiments package on the lunar surface. Samples of lunar terrain were taken, various photos were taken, and parts were taken back from Surveyor 3 for examination.

April 11, 1970

Apollo 13, an American spacecraft, was scheduled to stay on a 10-day lunar landing mission. The mission's purpose was the following: 1, to explore the Fra Mauro region of the Moon; 2, to perform selenological inspection, survey, and sampling of material in the Fra Mauro formation; 3, to deploy and activate an Apollo lunar surface experiments package; 4, to further develop man's capability to work in the lunar environment; and 5, to obtain pictures of possible lunar exploration sites. Because of a malfunction in the command service module, which made the command module unusable for the mission, the mission had to be aborted.

September 12, 1970

Luna 16, the sixteenth of the Soviet automatic interplanetary station series, was the first robotic probe to land on the Moon and return a sample to Earth.

October 20, 1970

Zond 8, a Soviet spacecraft, investigated the Moon and circumlunar space and tested onboard systems and units.

November 10, 1970

Luna 17, the seventeenth of the Soviet automatic interplanetary station series, landed on the Moon and let out the rover Lunokhod 1. Lunokhod traveled 10,540 meters, transmitted more than 20,000 TV pictures and more than 200 TV panoramas, and conducted more than 500 lunar soil tests.

January 31, 1971

Apollo 14, an American spacecraft, was the third Apollo mission to land humans on the Moon. Apollo 14 placed a lunar surface experiments package on the lunar surface, samples of the lunar surface were collected, and various frames of mapping film were taken.

Lunar Odyssey

Lunar Exploration Timeline

July 26, 1971

Apollo 15, an American spacecraft, was designed to land humans on the Moon. Apollo 15 was a 12-day scientific mission which included deployment of the Apollo lunar surface experiments package, geological field exploration, documenting pictures, and collecting samples of the lunar terrain.

September 2, 1971

Luna 18, the eighteenth of the Soviet automatic interplanetary station series, orbited around the Moon 54 times and headed towards the Moon's surface using braking rockets. Signals from Luna 18 ended at the moment of its impact on the Moon.

September 28, 1971

Luna 19, the nineteenth of the Soviet automatic interplanetary station series, was put into lunar orbit to study the lunar radiation environment, the gamma-active lunar surface, the solar wind, the lunar gravitational fields, and locations of mass concentrations.

February 14, 1972

Luna 20, the twentieth of the Soviet automatic interplanetary station series, was sent into lunar orbit and then soft landed on a mountainous area on the Moon. Luna 20 collected lunar samples by using an extendable drilling tool, and after samples were collected, Luna 20 returned and landed in the Soviet Union.

April 16, 1972

Apollo 16, an American spacecraft, was the fifth mission in the Apollo series in which humans landed on the Moon. In this eleven day scientific mission, Apollo 16 deployed the Apollo lunar surface experiments package on the surface, took terrain samples, took pictures, and tested the second lunar roving vehicle by exploring regions close to the landing site.

December 7, 1972

Apollo 17, an American spacecraft, was the sixth and last of the manned lunar landing missions in the Apollo series. Astronauts remained on the surface of the Moon for 73 hours and used a roving vehicle and rode up to 3 km from the landing site. While they were roaming around the Moon, they deployed several Apollo lunar surface experiments packages on the lunar surface and conducted geological studies. This mission found the first traces of orange-colored soil, indicating volcanic activity on the Moon.

January 8, 1973

Luna 21, the twenty-first of the Soviet automatic interplanetary station series, landed on the Moon and carried the second Soviet lunar rover Lunokhod 2. The objectives were to collect images of the lunar surface, examine ambient light levels to determine the feasibility of astronomical observations from the Moon, perform laser ranging experiments from Earth, observe solar x-rays, measure local magnetic fields, and study mechanical properties of the lunar surface material.

Lunar Odyssey

Lunar Exploration Timeline

June 2, 1974

Luna 22, the twenty-second of the Soviet automatic interplanetary station series, had the objectives to study the Moon's magnetic field, surface gamma ray emissions and composition of lunar surface rocks, the gravitational field, micrometeorites, and cosmic rays. Luna 22's mission was ended after maneuvering fuel ran out.

October 28, 1974

Luna 23, the twenty-third of the Soviet automatic interplanetary station series, was a Moon lander mission which had the mission of returning a lunar sample to Earth. The spacecraft was damaged during landing, and the collecting tool was damaged. No samples were returned.

August 14, 1976

Luna 24, the twenty-fourth of the Soviet automatic interplanetary station series, was the last of the Luna series. Luna 24 landed on the Moon and returned to Earth with 170 grams of lunar samples.

January 24, 1990

Hiten, a Japanese spacecraft, was used to verify the swingby technology of changing the course and speed of a probe by utilizing the gravity of the Moon.

January 25, 1994

Clementine, an American spacecraft, mapped most of the lunar surface at a number of resolutions and wavelengths.

November 23, 1997

Lunar Prospector, an American spacecraft, was designed for a low polar orbit investigation of the Moon which included mapping of surface composition and polar ice deposits, making measurements of magnetic and gravity fields, and the study of lunar outgassing events. Data has already been received that indicates the Moon has a very small core. The data from this mission may improve our understanding of the origin, evolution, current state, and resources of the Moon.

December 24, 1997

AsiaSat 3/HGS-1 was a communications satellite launched by Hong Kong, People's Republic of China. It made two successive flybys of the Moon. This was the first time such a maneuver was performed by a commercial satellite.