Voyager I:™

The Solar System

By Mike & Patty Westerfield

for Peg,
the teacher

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I would like to thank Dr. Jim Lupo for checking the documentation for technical errors, and Steve Paine for helping to track down the ephemerus for the asteroids.

The cover photo was provided by the Jet Propulsion Laboratory. We are grateful for its use, and for all they have done to bring better understanding of the solar system to all of us.

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What is Voyager?

Voyager is the first in a series of programs designed to bring you the science of astronomy on your personal computer. *Voyager 1: The Solar System* gives you an accurate top view oT the solar system, showing the positions of the planets and up to four other objects as they move around the Sun. What those other four objects are is up to you. The program has the data it needs to show the positions and orbits of sev~~ral major asteroids and comets, and a later section shows you what you need to do to add any other orbit to the program.

This may sound a bit complicated, but it really isn't The pull down menus make Voyager so easy to use that anyone who can read and point can use it. You won't need a mouse or joystick either, just the keyboard that came with the the computer. In fact, Voyager is so easy to use that only a few paragraphs of this book are devoted to telling you how to use it, and if you like experimenting, you probably won't even need that much information!

OK, so this seems like a thick book for such a simple program, right? That's because Voyager is simply a tool for your exploration of the solar system. Like a hand held drill, the tool is so simple that you can learn to use it in just a few minutes. But, like that drill, there are so many unexpected and enjoyable things that can be done with Voyager that we want to share them with you by giving step by step instructions on how to use Voyager to see some fascinating things about the solar system we live in.

If you aren't as fascinated as we are with these topics, or if you would just like to skip ahead, the Command Summary section starting on page 00 will describe the program in a traditional User's Manual style. Almost all of the information in that section is covered somewhere in one of the small journeys we will take, so don't feel like you need to skip there right away! We just wanted to point out the section early on for those who want to leave the tour.

Before going any farther, there is one quick step that you should do to protect your investment. Voyager comes on an unprotected disk. It is very important that you copy the original disk to a backup, and that you only use the copy, never the original. That way, if disaster ever strikes, you can simply make a new copy. Please keep in mind that copies are for backup purposes only and that any other use is a violation of copyright laws. If, for some reason, you need to use Voyager on more than one computer (like in a school) then give us a call - our multi-user licenses are very reasonably priced, and come with the opportunity to buy more manuals at reduced rates.

So fasten you seat belts and hang on, we're about to visit outer space!

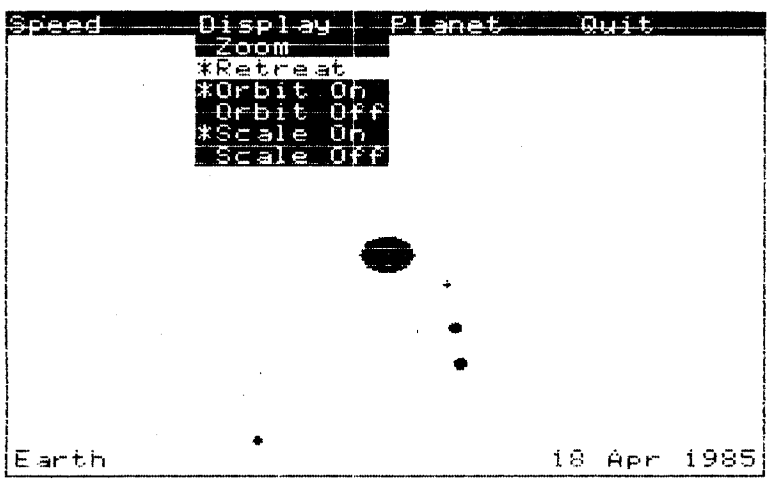
A Quick Look at the Solar System

One Small Step by Man ...

Lets start with a brief tour, just to get out feet in the vacuum. Put the program disk into your disk drive, close the drive door, and turn on your computer.

The first thing that you will see is the title page. Press R to continue, or just wait eventually, Voyager will proceed on to the main program by itself.

After a bit more whirring and a flash on the screen, you will see a picture like the one in Figure 1. This shows the inner four planets on some date. The date is the one shown at the bottom right of the screen. As you watch, the planets will move, and the date will change.



How do the planets move, and why can't you see them from the side? Later, when you look at Kepler's laws, we will find out a lot more about this, but we need a quick look into the matter now! There are at least nine planets that orbit around our Sun, the Earth that we live on being the third of the these, counting outward from the Sun. Did I say at least nine? Yes because of unexplained variations in the orbits of the outermost planets, many scientists are convinced that there is at least one more planet beyond the orbit of Pluto.

All of the planets move in elliptical orbits around the Sun. An ellipse is a sort of flattened circle; we will look closely at this idea in the section on Kepler's laws. The Sun is always in the same plane as the orbit of the planet. This means that if we draw the orbit of a planet on a sheet of paper, the sun would be on the sheet of paper, not above or below it. In addition, each of the orbits of the planets are nearly in the same plane. In other words, if we were to draw all of the orbits on the same sheet of paper, our drawing would be a fairly accurate one.

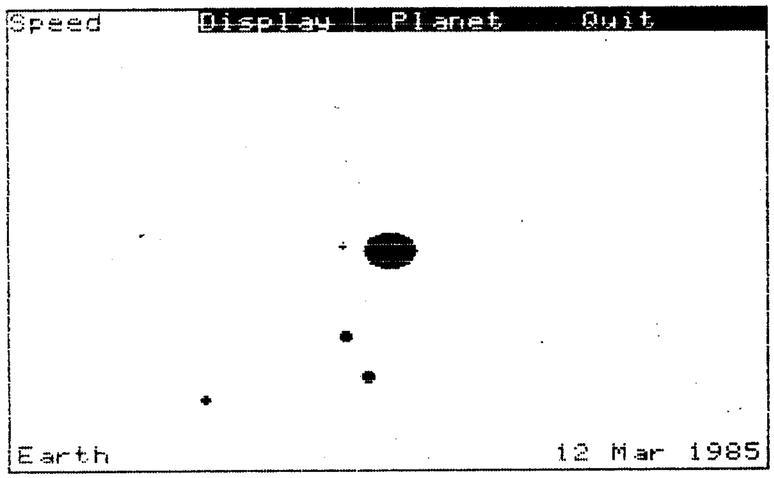
So, looking back at the screen, we get a better idea of what we are seeing. Since the orbits of the planets are all fairly flat, Voyager only shows them from the top.

Where Have All the Planets Gone?

Wait! There are nine planets, right? And only four on the screen.

The orbits of the planets vary a great deal in size. Very roughly, each orbit is about twice as big as the one before it. In fact, the orbit of Pluto is about 100 times the size of the orbit or Mercury! It should be fairly obvious that Voyager just can't clearly show all of those orbits on your computer screen. So what you see are the planets that it can show - the first four planets, Mercury, Venus, Earth and Mars.

Well, its time to do some exploring. After all, you probably want to see Pluto, right? To do this, we need to change the planets that we are looking at. At the top of your screen is a line of words, called a menu bar. The second word in says Display, and it is that word that we need to move to. Use the right and left arrow keys on your computer to move the black cursor over the word display. Now, type the down arrow key (or / or ? if your computer doesn't have an down arrow key). A group of words appears below the menu bar on your screen. This is called a pull down menu. The words that have asterisks to the left of them are options that you can select. For example, you can use the up and down arrows (' or " can be used as an up arrow) to move the cursor bar up and down the menu, then use the space bar when the cursor is on the word that you want. The item Retreat is the one we want. Place the cursor on it, as shown in Figure 2, and press the space bar.



What happened? First of all, Mercury and Venus are no longer on your screen. Instead, you see the Earth, Mars and Jupiter. Also, Zoom now has an asterisk in front of it. Up until now, you couldn't zoom in closer, since Mercury is the innermost planet, and it was already on your screen.

Explore for a while, zooming and retreating to get a feel for both the program, and the solar system.

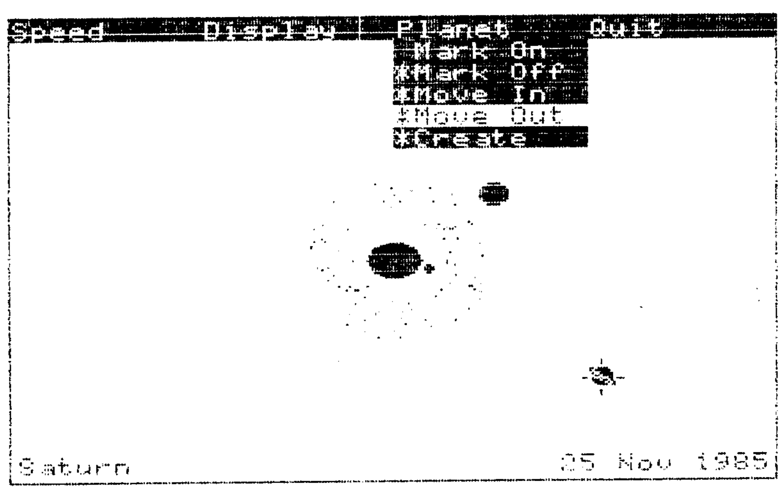
Which One is Which?

Until you get your Jr. Starship Captain wings, it may be a little difficult to tell the planets apart. Strange as it seems, some people just don't seem to have the order of the planets memorized! Well, we can fix that.

Of course, we won't make you memorize the planets if you don't want to. Instead, we will fix the problem by letting Voyager tell you which is which. In the bottom left corner of your screen is the name of a planet. By using a new pull down menu, Planet, you can use Move In and Move Out to change the name of the planet.. T-he plan t names appear in order, so that if you select Move Out while the name is Earth, it chanqes to Mars. The table below shows the names of the nine planets in order.

Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto

Well, that helps, but which planet is the one whose name appears? Pull down the Planet menu again, and select the item called Mark On. Depending on just how your screen is set, you may n;-t see a change. But if you continue to move in and out, you will eventually see a set of cross hairs appear around a planet, like the ones around Saturn in Figure 3. The cross hairs are on the same planet that is named in the lower right hand corner of the screen. With a map like that, you should never get lost again!



Looking at the Orbits

There are cases when you might want to see just what the orbit of the planets look like. Under the Display menu is an option called Orbit On. When selected, Voyager shows not only the current position of the planet, but the orbit, as well. The option Orbit Off, in the same menu, gets rid of them again.

The orbits can be used to verify one interesting fact about the solar system. Retreat all the way, so that you can see Pluto on the screen, and turn on the orbits. The orbits of Neptune and Pluto seem to collide! In fact, they actually cross. Right now, Pluto is not the ninth planet, but the eighth. It is closer to the sun then Neptune! This strange orbit causes many scientists to speculate about the possibility that Pluto is not really a planet at all, but a lost moon of Neptune, ripped out of orbit by some cataclysmic past event.

How Big is Big?

Later, we will make a model of the solar system to get an idea of some of the sizes involved in the solar system. For now, lets just start to get used to the units we use to measure distances.

So what's a unit? Stop for a moment, and think of how you would me-asure the length of a dollar bill. Would you do it in miles? Of course not - most people would use inches. Now, how would you measure the distance from New York to Chicago? Not in inches! The same problem occurs when we talk about distances in the solar system. Measuring the distance from the Sun to Pluto in miles is even worse than measuring the distance from New York to Chicago in inches. It turns out that Pluto can get as far as 3,669,525,713 miles from the Sun! Even the Earth, which is much closer than Pluto, is about 93,000,000 miles from the Sun.

Because of these extreme distances, scientists have invented a new unit of measurement for use in measuring distances around the solar system. It is called the Astronomical Unit, and is defined as the distance between the Sun and the Earth. The numbers are a little easier to manage and talk about that way!

Voyager will show you a scale in AUs if you ask for it. Go to the display menu and turn <u>Scale On</u>. At the bottom and left of the screen, a bar will appear. Above the bottom bar is a number, which tells you how long the bar is in AUs. The reason for two bars is that your screen may be adjusted so that one direction is stretched in relation to the other; if the bars look like they are about the same length, this is not a problem on your computer. Later, we will cover ways to dump the screen to a printer (how did you think we got those pictures?). In that case, the display is almost always stretched.

"Scottie, We're all Dead if I Don't Get Warp 10..."

By now, you may have noticed that the outer planets don't seem to move much. That's because they take so much longer to travel around their orbits, and when it starts, Voyager is trying to show you the motion of the inner four planets. The speed menu, on the far left of the menu bar, lets you speed things up.

Move out to where you are looking at Pluto. Now bring down the Speed menu. Try Faster and Slower - they change the third entry. You may also notice a difference in the way the date changes. The third number is the number of days that elapse between screen updates. The first two options let you change it by 1.

That's no help, though. When looking at Pluto, you probably want a year between updates, not a few days! So try the third option. You get a chance to type in any integer number of days, all in one change. Enter 365 (one year) for now. There - aren't the planets moving better?

The next two options let you stop and start the movement, and let you enter a specific date for Voyager to display the planet positions. Go ahead and experiment - you can't hurt anything.

A Tour of the Planets

This section has very little to do with the program itself, but it would be a shame not to stop for a moment and take a mental tour of the planets whose orbits we are now looking at. As we go through the major bodies of the solar system, we will build a model with dimensions that we can grasp, just to get a better idea of some of the sizes involved. We will not talk about asteroids or comets here, since they are covered in special sections later on.

The Sun

At the center of our solar system is a fairly average star. It gives off a yellowish light due to a continuous nuclear reaction going on at its center. The Sun is so far away from the Earth that it takes eight minutes for light to travel from it to us.

Our solar system model starts there, with the Sun. Imagine yourself standing on the goal line of a football field. In your hand, you hold a basketball, which represents the Sun. It is 12 inches in diameter, and of course, is painted bright yellow. Now prepare yourself - Figure 4 shows the planets, drawn to the correct scale for our 12 inch Sun!

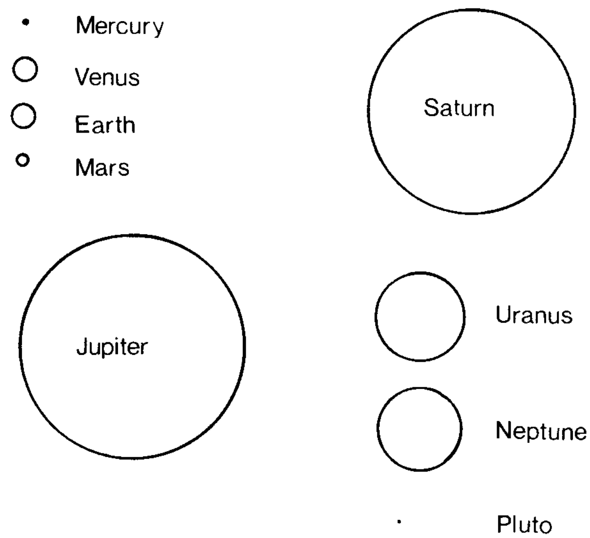


Figure 4

Mercury

As you look out across the football field, you no doubt see the planet Mercury. You know, the one that's about the size of a pinhead in Figure 4. Its right there - almost at the 14 yard mark. Not even first and goal.

Mercury is a small, forbidding planet that resembles our moon a great deal. It has no atmosphere, partially due to its small size and partially because of the heat given off by the Sun. Surface temperatures on Mercury can melt tin or lead (which melt at 449 and 621 degrees fahrenheit, respectively), while on the dark side, water can occasionally freeze. Their highway department has a heck of a time.

Venus

Just past the 26 yard line is a very bright planet called Venus. In our model, its about twice the size of a pencil lead; you would have to line ten of them up to get an inch. The most distinctive feature of Venus is its dense layer of clouds. These have a slightly yellow color, but reflect light very well. Venus is so close to the size of the Earth that they are considered twin planets. This is despite the fact that the surface temperature of Venus is too hot for liquid water!

Earth

Almost at the 35 yard line is another planet, only slightly larger than Venus. This planet is noteworthy for two reasons. First, two thirds of its surface is covered with water. Secondly, it is almost a double planet - it has a satellite (the moon) that is nearly a quarter its own size!

Oh yes - a few consider it important that it is the only planet so far known to support life forms. Only time will tell if they are intelligent.

Mars

Continuing our tour, we find a striking red planet at the 54 yard line. It is about half the size of the water planet, with two small moons of its own. Frozen water can be seen at the poles during the winter seasons, and there is a fairly dense atmosphere. Mars holds claim to the largest known volcano and the largest known canyon in the solar system.

Jupiter

Finally, we get to some planets that are significant! So far, all of the planets have been small, rocky, and fairly uninteresting. Jupiter, the largest planet in the solar system, was almost a star. In fact, due to continual gravitational collapse, it still gives off more energy than it receives from the Sun. It is a beautiful, swirling mass of yellow and orange gasses, with occasional white spots formed by giant storms, and a distinctive red spot that is a large storm, known to have been raging for several hundred years. It has over a dozen moons, four of them quite large. Very faint rings of dust extend down almost to the atmosphere, where the particles are finally captured. In our model, it is about the size of a golf ball. Unfortunately, it is not in the football stadium - at 560 feet away, it is almost two football fields into the distance.

Saturn

The second largest planet in the solar system is perhaps the most striking. With rings that are larger than Jupiter and the same orange and yellow coloring, it is a beautiful planet. A little smaller than Jupiter, it is two tenths of a mile away from the goal line in our model (1025 feet, or about 3 1/3 football fields). It has several moons, including one with a fairly heavy atmosphere. Due to its atmosphere, it way long believed that Titan was the largest moon in the solar system, but recent NASA fly bys have shown that it is a little smaller than Ganymede, one of Jupiter's moons.

Uranus

The planets continue to get smaller as we look 4/10 of a mile away at another gas giant, Uranus. It is seven football field lengths away, and about half the size of dime. It has at least five moons, none of them very large. Uranus has a very faint ring structure.

Neptune

About the same size and composition of Uranus is Neptune, the last of the giant gas planets. It has two known moons. It is half again as far away from the Sun as Uranus, a full 6/10 of a mile in our model.

Pluto

The last planet is a small, rocky planet much like the inner four. Although only slightly larger than Mercury, it does have a moon of its own. At 8/10 of a mile away from the starting point on our football field, it is the farthest known planet. That's 14 football fields away. And its very, very cold! This may not be the last planet in the solar system - sharp eyed observers have noticed very small difference in the positions of the planets from what they expect, causing them to believe that there is another one out there.

Asteroids

Bodes Law

One of the most amazing things about the Solar System is how regular it is. As we saw earlier, the orbits of the planets are nearly circular, and all lie in about the same plane.

Another amazing fact was discovered in 1772 by Titus of Wittenburg and, independently, by Bode. If you look at the average orbital distance of the planets from the sun in terms of AUs, where d is the distance and n is the planet number (Earth is 1, Venus 0, and Mercury 1), the formula

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d = 0.4 + 0.3(2**n)
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predicts the values very well. It should be pointed out that the formula could be generated in terms of any planet. The position of the Earth is not special in the formula, it is our own prejudice which cause us to write it that way. The table below shows the orbital distances of the planets as predicted by Bodes law, as well as the actual distances. Except for Neptune and Pluto, the agreement is startling!

Planet	Bodes Law	Actual
Mercury	0.4	0.39
Venus	0.7	0.72
Earth	1.0	1.00
Mars	1.6	1.52
(missing)	2.8	
Jupiter	5.2	5.20
Saturn	10.0	9.55
Uranus	19.6	19.20
Neptune	38.8	30.10
Pluto	77.2	39.5

Of course, there)s the minor problem that a planet is missing between Mars and Jupiter. This was very disturbing indeed, and some thought that because of it, Bodes law was nothing more than a coincidence. But then, on I January 1801, the Italian Piazzi observed an object in his telescope that looked like a star, but was not there the night before! Several days of observation showed that it moved, so it was definitely a planet of some sort. Soon, however, the new object was lost. Fortunately, the mathematician Gauss had just devised a method of calculating an orbit after just a few sightings. The new orbit was at 2.8 AU, in excellent agreement with Bodes law! The object is now known as Ceres, one of 3000 known asteroids. It is the asteroid belt that you see in Voyager as a spotted area between Mars and Jupiter.

A Closer Look

Voyager has a capability which we have not used up until now. It can show up to four objects in addition to the nine planets. Your disk has several objects that can be seen, including the four largest asteroids. The asteroids that you can see with Voyager, as well as some interesting data about them, is shown in the table below.

Name	Diameter in Kilometers	Average Distance in AUs
Ceres	372	2.7686
Pallas	238	2.7686
Juno	103	2.6703
Vesta	195	2.3608
Earth's Moon	1738	0.0026

To see one of the asteroids plotted on your screen, start by selecting Create, under the Planet menu. The program will ask you to select one of the four positions to put the new object; which one you pick is up to you. If you have already filled one of the slots, the name of the object will appear beside the number to let you know that its there.

After selecting a spot to put the object in, Voyager will look at its internal data base and present you with one of the things that it finds there. The program can only show one thing at a time, but you can use the up and down arrows to scroll through the entire list. Just for practice, select Ceres, which is first in the list.

Now, if you set the screen to show the asteroid belt, a strange new object appears among the asteroids! You can use the usual methods to turn its orbit on or off, and to see its name and have a marker placed on it. Look closely - it is small.

The Trojans

A remarkable group of asteroids known as the Trojan group illustrate the fact that there is a "gravity well" created by the orbits of two large bodies * The two largest bodies in the solar system ar the Sun and Jupiter, so we would expect to find it there, if anywhere. In fact we do - one sixth of an orbit in front of Jupiter are seven asteroids, and one sixth of an orbit behind are five others. The orbits of these remarkable asteroids can be seen by adding TROJAN.L and TROJAN.F to your display, just like you added Ceres. Turn on the orbits - notice that they match Jupiter's exactly!

Comets

Comets are one of the most interesting, beautiful, and misunderstood members of our solar system. To understand them, we will have to start by taking a close look at just what a comet is.

Comets are believed to be formed at the very edge of the solar system, about 150,000 AU from the Sun. At that distance there may be as many as 100,000,000,000 comets in random orbits. This group of comets is known as Oort's cloud, named after the man who proposed and the studied idea. Occasionally, possibly due to collision or tiny gravitational tugs from passing stars, the orbit of a comet is changed enough that it passes close to the Sun. In fact, comets have been observed to hit the Sun!

As a comet approaches the Sun, it begins to put on a spectacular show. Comets are made up of frozen water, methane, ammonia, and tiny particles of iron and nickel dust. These materials are frozen in a small ball known as the nucleus. As the comet gets closer to the Sun, part of it evaporates. Once it becomes a gas, it begins to glow in the sunlight. This part of the comet is called the coma. As the comet gets even closer to the Sun, it forms a spectacular tail, which can be as long as 100,000,000 miles! Keep in mind that the Earth is only 93,000,000 miles from the Sun.

When Voyager shows you a comet, it uses a symbol very different form the simple circle used for the planets, giving the comet the tail it deserves. On the other hand, the tail is simply part of the symbol, and does not change the way the tail of a real comet would. On a real comet, the tail starts to form as the comet comes in past the orbit of Jupiter, getting longer as the comet gets closer to the Sun. Since the tail is formed by the solar wind blowing the gasses away from the Sun, it always points away from the Sun.

Voyager's data base contains the orbits of several well known comets, including Halley's comet, which is the most famous. Two important facts must be kept in mind when looking at the orbits of the comets using Voyager. The first is that Voyager shows a top view of the solar system, and, unlike the planets, the orbits of comets do not lie in a neat plane. Comets come in and go out at some rather unusual angles.

The second major thing to keep in mind is that comets are very small objects compared to the planets, ranging from a few miles to a few hundred miles in diameter at the nucleus. They are also very light, with the largest only about a millionth of the Earth's mass. As a result, their orbits are frequently effected by close encounters with the planets. Voyager only takes the gravitational attraction of the Sun into account, so any change in the orbit due to a close pass by a planet will not be seen.

Comets are contained in the same data base as the asteroids, and are loaded and looked at the same way. The table below lists the three comets in the data base. Inclination is an orbital parameter that tells how much the orbit of an object varies from the plane that the planets are in. Halley's comet has an inclination so large that it is almost tipped over! In fact, Halley's comet travels in a clockwise orbit, while most other objects travel around the sun in a counter-clockwise orbit.

Comet	Period in Years	Inclination	Eccentricity	Average Distance in AUs
Encke	3.30	12.4	0.847	2.21
Oterma	7.89	4.0	0.144	3.96
Halley	76.2	162.3	0.967	17.8

The Jupiter Effect

In 1971 John R. Gribbin and Stephan H. Plagemann wrote a book called The Jupiter Effect. In the book, they pointed out that in early 1982 all of the planets would be lined up on the same side of the Sun. Although gravitational pulls from the planets are quite small, they are detectable. The book pointed out that the small extra tugs from all of the planets lining up at once might be large enough to cause increase sunspot activity, or to trigger several large earth quakes. Historical searches seemed to indicate that the same thing might have happened in the past.

Since the ideas proposed did not call for a single day of cataclysmic events, but rather a gradual build up of such occurrences, it was possible to discover that these ideas were wrong long before the planets actually lined up. A retraction was published, but of course, a retraction is not deemed quite as sensational as a prediction, so very few people ever heard about it. In fact, the book predicting the events was on book shelves long after the retraction had been published!

So what did Gribbin and Plagemann mean, that the planets would line up? By looking at the cover of the book, you might think that all of the planets would form a perfectly straight line. Use the date function to position the planets to early 1982, and stop the motion. How do they look? Watch the planets as the Earth moves between the Sun and the larger planets. Do they really line up?

Kepler's Laws

In the 1500s it was still firmly believed by the intellectual community that the Earth was the center of the universe, and that the Sun and planets rotated around the Earth. By this time, a great deal of evidence had piled up to firmly indicate that the Earth was not at the center, but the leaders of the day simply would not be confused by the facts; they were, after all, sure that they were right.

By the time Kepler began looking at the motions of the planets in the early 1600s, it was at least not unheard of for intellectual mavericks to believe that the Sun, not the Earth, was the center of the universe. Modern physics would eventually lead to the understanding that there is no such thing as a center of the universe, but we work in small steps! Eventually, Kepler's work lead to a set of rules governing the motion of the planets that were so simple compared to the older methods that they could not be ignored. It was left to Newton to explain why the rules worked. The rules became known as Kepler's Laws.

The First Law

The first and second laws were discovered in 1609 as Kepler analyzed the painstakingly accurate observations of the positions of the planets made by by his predecessor, Bycho Brache. An interesting historical footnote is that Brache was convinced that the Earth was the center of the universe, and hoped that his data would prove it! Kepler's first law states that the shape of the orbit of a planet (or any other object in a closed orbit, as it turns out) is an ellipse. Further, the Sun is at one of the focci of the ellipse.

So what's an ellipse? Earlier, an ellipse was described as a flattened circle. In fact, a circle is actually an ellipse without any flattening. Figure 5 shows how to draw an ellipse. First, place two tacks through a sheet of paper, and tie a loop of string loosely around the tacks. Next, draw a pencil line by stretching the string out into a triangle and drawing around the tacks. The result is an ellipse. For an orbit, the Sun would be where one of the tacks was.

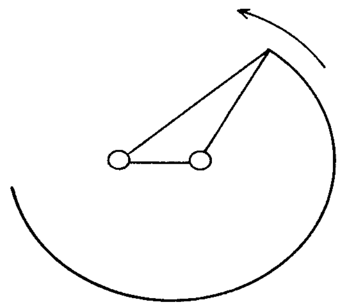

Figure 5

Now, what happens if the tacks are placed at the same place? You get a circle! This is what was meant when we said that a circle is an ellipse without any flattening.

The Second Law

Kepler's second law lets you know how fast a planet moves at any point on its orbit. It states that a planet sweeps out equal areas in equal times, as shown in Figure 6. To cover the required distance when close to the Sun means that the planet will travel faster when it is close to the Sun than it does when is is farther away. This effect can actually be seen with Voyager when you look at comet orbits.

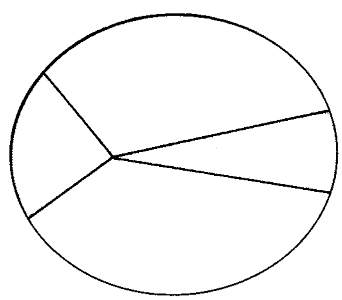

Figure 6

Even more interesting is to verify the law exactly. To do this, start by plotting the position of Mercury's orbit over successive 10 day intervals.

Now place a sheet of thin graph paper over the orbit, and count the squares that are inside of the section of the orbit. The number of squares gives a good approximation of the area swept out by the planet during the 10 day interval. It should match very closely with the areas you measure for the other 10 day intervals.

The Third Law

It wasn't until 1619 that Kepler discovered the last of the three laws, and no wonder! It says that if you solve the equation

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P**2 = C * (d**3)
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for c, where p is the period of a planet and d is average distance from the Sun, that the constant c will be the same for all of the planets. So, once you know the distance for one planet and have measured the periods of the planets, it is possible to calculate the distances for all of the other planets. The table below gives the average distance for the planets and a few asteroids and comets, so that you can check Kepler's work.

Name	Average Distance in AUs	Orbital Period in Days
Mercury	0.3874	87.99
Venus	0.7228	224.70
Earth	1.0000	365.26
Mars	1.5233	686.98
Jupiter	5.2025	4332.42
Saturn	9.5407	10759.28
Uranus	19.190	30684.49
Neptune	30.086	60188.40
Pluto	39.507	90711.42
Ceres	2.7686	1679.96
Pallas	2.7686	1684.96
Juno	2.6703	1593.98
Vesta	2.3608	1326.03
Encke	2.21	1205.35
Halley	17.8	27832.54
Oterma	3.96	2881.87

Why Should You Check the Laws?

Kepler was a pretty smart man, and a lot of other smart people have said that the laws work. That's the way it is with a lot of science. So why should you bother to check the work, when you know it's right?

Do you really know its right? Are you really sure? The basis for science is that you don't have to believe a smart person. There are a lot of smart people who will be happy to tell you what they believe, but that doesn't make their beliefs true. (It also doesn't make them false.) The difference between science and other intellectual pursuits is that with science, you must be able to check the results. So go ahead - Maybe you've been lied to!

Using Voyager in the Classroom

The Voyager series of programs is primarily intended for home use, which is why the manual has been written the way that it has. We believe that there are a lot of curious people out there who would like to discover things for themselves, and we want to help.

Of course, that doesn't mean that the program can't be used in a school. In fact, we hope it does get used there, too, and insured that high school teachers got a chance to look at and comment on the program before it was published in order to make that easier. This section is designed to help the teacher make use of the program.

The following sections have a list of activities that can be used as classroom laboratory exercises. They are divided into three sections, based on very rough divisions in the level of the student. The first of these sections is intended for students with little or no background in mathematics beyond simple algebra. With help from the teacher, any of these activities could be carried out by preschoolers, but are more appropriate for the 10-15 age group. The second group of problems are a bit more advanced, requiring some knowledge of science or algebra. The last group of problems requires specific knowledge of physics at at least the high school level. The fact that a problem does not involve mathematics doesn't mean that there is nothing to learn from it, and certainly doesn't mean that it isn't fun!

If you are using Voyager in a school, you will probably want to purchase a multi-user license for the program. Without the license, the program can only be legally used on one machine. The multi-user license in inexpensive and comes with other fringe benefits, like the ability to buy several copies of this manual that comes with the program.

Problems Without Math

1. Plot the planets on February 1, 1984, the date of the Jupiter effect.

2. Plot the planets on other special days. One good example would be your birthday.

3. Add Halley's comet to Voyager and check its position. When will it come closest to the Sun? Where is the Earth at that time? Will we get a good view on its next trip to the Sun?

Problems Requiring Math or Science

1. The Earth takes about 356.25 days to travel around the Sun. How many times does it spin on its axis during a year? (Hint: it is not 365.25!)

2. If you plot the position of one of the outer planets against the stars, it will seem to change direction as the Earth passes between it and the Sun. Why?

3. Verify Kepler's first law.

4. Verify Kepler's second law for Pluto.

5. Verify Kepler's third law using the table on page 00. Use your results to compute the average distance for Halley's comet, which has a period of 76.2 years. Where is this in relation to the planets?

6. Assume the Earth is four inches from the Sun. Compute the distance for all of the other planets. Now take a string and tie small beads at the appropriate place and lay it out flat.

7. In the section that described the planets, we did a thought experiment where we scaled the Sun to the size of a basketball. How far away would the closest star, Proxima Centauri, be? (It is 270,334 AU from the Sun.)

Problems Requiring Advanced Knowledge

1. Find the necessary information and add an object to the Voyager data base.

2. Does Kepler's third law apply to objects orbiting the Earth? Sure - but the constant is different. Use this fact, the orbit of the moon, and the fact that satellites orbit at about 100 miles above the Earth's surface to calculate a typical orbital time for a satellite.

3. How large does the Sun look from Pluto?

Command Summary

This section gives a concise description of the commands available in Voyager, as well as a description of other special capabilities of the program. The next section describes a utility program which lets you add new objects to Voyager. It is not necessary to read this section to use the program. This section is intended solely for reference.

Using Pull Down Menus

Voyager is made simple and easy to use primarily through the use of pull down menus. Across the top of the screen is a menu bar, with four words on it. The first three words, Speed, Display, and Planet, are the names of the menus used by Voyager. To select a pull down menu, use the left and right arrow keys to move the cursor over the desired menu. The cursor is the inverse bar that causes a word to be shown as white on black, rather than black on white.

Once the cursor is on the menu that you want to see, use the down arrow to get a look at it. The up and down arrow keys can now be used to move the cursor up and down in the menu. If you use the up arrow key while the cursor is on the top item in a menu, the menu will disappear and the cursor will be place back onto the menu bar.

If your computer does not have up or down arrow keys, you can use ' or " for the up arrow, and / or ? for the down arrow.

As you look at the menu, you will see that some of the items in the menu have asterisks on the left. These are the options which you can currently select. If an asterisk does not appear, the menu option is not currently available. Once conditions are changed so that the option is again available, an asterisk will appear.

To activate a menu option, press the space bar. (Actually, any key other than an arrow key will work.)

Speed

Each time Voyager updates the screen, it moves the planets a distance corresponding to how far they would move in a certain number of days. The number of days is shown in the third menu option. Faster and Slower, the first two options in this menu, will change the number of days by 1. Faster adds one, and Slower subtracts one. The third menu option will stop and prompt you for an integer between I and 32767, changing the number of days between updates to the number you enter.

Stop and Start let you stop the planets on a certain day, then restart them again.

The last menu option lets you enter a date, after which Voyager will change the planet positions to their positions on that day. All dates are entered using our current calendar. This means that very ancient dates recorded in history books may not be appropriate for use with Voyager, since our current calendar has not always been used. Consult a good reference book before using very old dates.

Display

The first two options in this menu, Zoom and Retreat, control which planets are displayed on the screen at any one time. Zoom acts like a zoom lens, moving the display in closer to the Sun, and thus cutting out the outermost planet on the display. Retreat does just the opposite - it moves back, showing a larger view, and thus looses some detail in the middle.

Orbit On and Orbit Off allow you to see the orbits of the planets.

Scale On and Scale Off control the display of a bar to the left and bottom of the screen which give scale information about the current display. The bottom bar is flagged with a number indicating the size of the bars in Astronomical Units (AU). One AU is about 93,000,000 miles.

Planets

The first two items in this menu are Mark On and Mark Off. When defined, each of the planets has two shapes. One of these is generally a circle of an appropriate size, while the other is a circle with cross hairs drawn around it. When Mark On has been selected and the planet whose name appears at T-he lower left of the screen is on the display, the second shape is drawn instead of the first. This gives a convenient way of seeing which planet is on the screen at a particular time.

Move In and Move Out let you select the planet whose name appears at the lower left of the screen.

Create is used to add up to four solar orbiting objects to the nine planets displayed on the screen. You will be asked to select which of the four available slots to place the new object, then given a menu which contains all of the valid data that Voyager can access. Use the up and down arrows to move the cursor onto the desired object, then press the space bar. For Voyager to be able to see the data, it must be generated by the data base program and placed in the directory /VGER1/ORBITS. See the next section for details on creating your own data entries.

Quit

Quit in not really a pull down menu, despite the fact that it appears on the menu bar. Instead, it is an option that lets you exit the program. If you move the cursor to Quit and hit the space bar, Voyager will stop and return control to the title page. From the title page, you can re-enter the program or exit to BASIC. From BASIC, the database program can be used to create new planets.

Printer Dumps

Voyager cannot dump a screen directly to your printer. There are just too many combinations to allow that. Instead, you can dump the screen to a disk, then dump the disk file to your printer with a program for that purpose.

To cause Voyager to dump the screen to disk, type CTRL-D. You can do this at any time. A window will appear, and you will be asked for a file name. Any legal ProDOS file name will work. The screen is written out to the file, and the window disappears.

Adding New Objects

In addition to displaying the nine known planets, Voyager can display the orbits and positions of up to four other objects. The only requirement is that the object must be in orbit around the Sun. This orbit must be a closed orbit. That means that the object must keep on orbiting, not simply skim past the Sun, continuing on to another star later on.

Two methods are available for dealing with these extra objects. The first is fairly simple, and can be learned by anyone. It involves telling Voyager to select an object from its precomputed database. We did this in the sections dealing with asteroids and comets. The second method involves taking an object that Voyager knows nothing about and telling the program enough about the object that Voyager can show its orbit. This is a fairly complex process which requires a good background in both mathematics and astronomy, so it's not for everyone. But if you don't want to do it, don't worry too much. Voyager's existing data base has many of the most interesting comets and asteroids, so adding other objects to the data base is really not necessary.

If you want to see the orbit of an object other than a planet or one of the comets or asteroids in the existing database, you will have to create a new database entry. This is done with the aid of a separate database program called DBASE. It is on the subdirectory /VGER1/ORBITS.

To get to DBASE, first boot the Voyager disk, then exit the program using the QUIT menu option. This places you in the hands of ProDOS, in SYSTEM.BASIC. Next type

```
PREFIX ORBITS
-DBASE
```

to enter the database program. There are four steps to adding an object to the database. The first, and most fun, part of creating the database is to define the shapes that will show up on the screen when the object is drawn. The two large boxes show expanded views of the two shapes; actual size drawings are shown just above each of the boxes. Your shape should be centered in the box. The left shape will be drawn by Voyager when <u>Mark Off</u> is selected, and the right hand shape when <u>Mark On</u> is selected and the shape's name is in the lower left corner of the screen. To edit the shapes, start by typing E. A flashing cursor will appear in the left box, and a new prompt line shows up at the bottom. As indicated, U K L and R can be used to move the cursor, and S to select a point. Selecting a point changes the color of the point that the cursor is on. When the first shape is edited, use N to move on to the next one. When it is finished, using N again will exit the shape edit mode. The process can be repeated to re-edit the shapes.

The next step is the hard one. The database program needs some very specific information about the orbit of the object, and it is up to you to give that information. After entering a C to change these parameters, you will be prompted for the following things:
28

e - Eccentricity. This number tells how round the orbit is. An eccentricity of zero indicates aperfectly round orbit, while one indicated a line which passes through the Sun. These numbers can be fairly large for comets, but are generally no larger than 0.3 for asteroids. See the note below for very large eccentricities.

name - This is just the eight character string to print at the lower left of the screen when Move Out or Move In is used to point to the new object. It must -also be a valid ProDOS file name.

Period - This the amount of time that it takes the object to make one complete orbit around the Sun. Accuracy on this number is of the utmost importance. It is given in days.

RO - This is the distance from the Sun to the object when it is closest to the Sun. Reference books will call this distance the perigee. The number is given in AUs.

theta0 - The angle between a line from the Sun to the vernal equinox, given in radians, on 1 January 1985. In reference books, this is called the heliocentric ephemerus.

tilt - The angle between the vernal equinox and the object's perigee. This tells Voyager how to align the orbit with relation to the other objects on the screen. The perigee is the point where the object is closest to the Sun.

The next step is a cake walk after that one. Simply press Q. The program will take a few minutes to compute the tables used by Voyager, then it will write the file out.

Two problems can occur when entering a new orbit into Voyager. The first is that the eccentricity of the orbit can be so large that the database program cannot compute the orbit. When the program finishes, it prints out a single number. It should be very close to either 0 or 2*pi (6.2831853). If it is not, then the program is having trouble. To fix it change line 3348 so that LM is an integer larger than one. The larger the integer, the more carefully the orbit is computed, and the longer it takes, For Halley's comet, we had to set LM to eight. For all other objects, one did just fine.

The other problem also occurred only with Halley's comet. The inclination of an orbit (given in tables as i) is that angle between the orbit and the plane of the ecliptic. The plane of the ecliptic, roughly speaking, is the plane that all of the planets are in. As was mentioned before, Voyager only shows the part of an orbit that is in the plane of the ecliptic, so we usually ignore the inclination. However, if the inclination is greater than 90 degrees, the object travels backwards. The inclination for Halley's comet is 162.3, so it should travel backwards. To cause this, add a new line to the program:

```
2180 H = -H
```

Now that the data exists for a new object, it is time to tell Voyager that it exists. This is done with a program called CREATELIST. To use it, load the program and list it. The first DATA statement is the number of objects in the data base, which you must increase by one. Next, add a new data statement at the end of the list with the file name of the new object, and run the program.

You can now load and display the new object just like you did for the asteroids and comets.