A scale model of
Our Solar System.

Background

Some time ago I was able to find a company in America that sold Earth and Moon globes that were in proportion to each other, the Earthball is about 16 inches in diameter and the Moon about 4 inches. The Moon is particularly interesting in that it is mounted on a base but is able to spin in two directions, at the same time! An interesting engineering solution it its own right and most people are fascinated by the solution. Many of the main features are labelled and the landing sites of all the Apollo missions and other unmanned probes are also indicated. Unlike other world globes I have seen, the Earthball is made up of satellite photos and contains no political borders. All of the major cities are indicated with luminescent paint. If you “charge it up” in bright sunlight and take it into a dark room, you can clearly see what the Earth looks like from space.

Unfortunately, most globes are made to a standard 9 or 12 inch diameter, which makes it very difficult to get a true idea of the proportions, but when I received my two globes I was able to clearly see just how small the Moon is compared to the Earth, about the same size as Australia. At this same scale, the Moon is actually some 12 metres away from the Earth. I liked my small Earth and Moon system so much, I decided to try to create my own complete, or as near as I could make it, solar system at the same scale, unfortunately I am unable to show neither the relative distances nor the sizes of the four giant planets. As a starting point, I downloaded some gores of Jupiter’s moons from:

http://astrogeology.usgs.gov/Gallery/MapsAndGlobes/joviansatellites.html

These allow you to create 9-inch globes of each of Jupiter’s four Galilean Moons. But considering Ganymede is 50% larger than of our Moon and Europa considerably smaller, such a task would hardly covey much of an idea of the true scale so I proceeded to think of a method of creating a series of globes the correct size for each one. After completing these moons, I continued on my task and ended up creating more than three dozen scale models of planets, moons and dwarf planets and have created the table at the end of this document to give you an idea of sizes involved. From start to finish, it has occupied my spare time for the last 5 months, or about 500 hours!

Choosing a suitable scale

The first task is to calculate how big each model needs to be. I decided to make the Moon globe my reference as the Earthball was inflatable and so its size will vary depending on temperature, I soon learned that blowing these things up with the warm air from your lungs is not a good idea. On a warm day, the globe is quite firm but on a cold day it becomes severely deflated and looks like an Earth that has been involved in a head on crash! I subsequently reinflated it with air from a hand pump which keeps it well inflated even on cold nights.

The printing on the Moon globe says it is produced on a scale of 1:32,000,000 (32 million to one). With a nominal Lunar diameter of 3745 kilometres this gives a scaled diameter of:

3745×10^3 metres / 32×10^6 = 3.745 / 32 metres = 0.117m or 117mm

However, measuring a diameter is not a very easy task. Using simple high school maths says that multiplying the diameter by π (pi) will give the circumference, which can be easily checked by wrapping a tape measure around each sphere as they are created. So a diameter of 117mm comes out to:

117 x 3.14 = 367mm

However, after checking the circumference of the globe I found it to actually be 348mm, indicating an error of 347 / 367 or 0.95 times what they stated, or 30.4 million to one. To keep everything in proportion I would create everything at this scale. This would make the formula:

π x D (km) x 10^6 / 30.4 x 10^6 = 3.14 x D/30.4 = 0.103 x D = circumference in mm

As you can see, to within a very small margin, our effective scale is very simple to work out, simply take the diameter in kilometres and divide it by ten to get the circumference in millimetres, how easy is that. I have used this simple factor to create all of the entries in the table at the end of this document. To check the accuracy of my Earthball, a diameter of 12,756km will require a circumference of 1.28 metres. I measured the Earthball as 1.32 metres, giving an error of 1.32 / 1.28 = 1.03 or in other words, the Earthball is just 3% bigger than it should be…not bad if you ask me. So now I am happy. If I can make each of my globes to within just a few percent of the required sizes, everything will be close enough that you won't notice the error unless you check it with a tape measure.

Finding a base for everything

It is immediately obvious from the sizes of the giant planets in the table that making scale models of them is simply out of the question, Jupiter would be just over 4.5metres in diameter…too large fit under the ceilings of most houses, let alone through a door…but I am working on this one. The four giant planets are therefore off my list, however, a "Hoberman Megasphere" is very close to the size of Neptune and fits in a small box, but their largest moons are certainly achievable.

Figure 1. Checking a small soccer ball for size.

So the next stage was thinking of something to use as a base to build up to the required size using paper Mache without having to spend too much time applying glue and paper. I headed to a sports store with a tape measure and table of sizes in hand and searched for various balls of a suitable size. I estimated that I would need about 10mm of paper Mache to cover any seems or stitching on each of the underlying balls and so I subtracted about 30mm (10mm x pi) from each circumference to get a ballpark size to look for. The base for Jupiter's two smallest moons was perfect for ten and a half inch softballs; these are stated in their circumference. Titan and the two larger moons were 30 to 40mm larger than a small soccer ball. Midsized objects, like Pluto and Eris, were similar to standard sized rubber balls while the smaller objects, less than 150mm, used large glass marbles that I found at a local $2 shop, these were fast to get to a final size but turned out to be slippery little suckers and often shot out of my hands and onto the ground. Finally, the tiniest (less than 50mm) were simply balls of paper built up to the required size.

Figure 2. Checking a softball for size.

Getting started

Now it is time to get down and get dirty, or sticky at least. I knew I would need large quantities of glue of some sort and decided on wallpaper paste. This comes in a small bag of 50g and is not cheap at around $10 but it will make up 4 litres of glue, and trust me, you will need it. Don't put too much of the powder into the water or you will end up with thick jelly rather than glue. I mixed up a sprinkling of powder in about 10 to 20 mm of water on the bottom of an ice cream container and found this allowed me to have a break after an hour or so of pasting. Initially I placed pieces of paper into the glue and applied them to the surface of the ball but quickly decided to just dip my fingers into the pot and rub a small quantity over the surface.

The first couple of layers will be rather difficult as the paper will tend to slide over the surface, however, once a couple of layers have been completed, it will stay in place and you can really get going. I quickly got into a pattern of picking up a piece of paper with my sticky finger tips and placing it on the surface, rub it over with my hand and pick up the next piece. Every minute or so you will need to pick up some more glue and apply it over the area you are working on, then rotate the ball to another position. This should be done randomly to ensure that the thickness is built up evenly over the surface. Don't be tempted to use very large pieces of paper, as these will very quickly build a very rough finish with a very lumpy appearance and the paper will often crease making the final surface even rougher. I found strips of paper no more than about a quarter of the circumference of the ball in length and maybe one or two centimetres wide were perfect, even smaller for the smallest moons and dwarf planets. If the pieces are too small you will get a smooth surface finish but you will take forever to build up any thickness.

The easiest way I found to tear up thousands of pieces of newspaper was to use a ruler as a guide and to place this along the end of 5 or 6 sheets of newspaper and then tear a strip along the edge, then tear the strip into suitable lengths.

After a while of pasting, check the circumference with a tape measure to ensure you don’t go oversize and have to tear some of the paper off again. Newspaper has a thickness of around 0.07mm and so it will take about 15 layers to add just 1mm to the thickness of paper, and about 3mm to the circumference.

Figure 3. The pasting begins.

After some time the ball will begin to approach the final size. I suggest leaving each one to dry

Figure 4. Measure as you go.

for at least a day before doing a final check of the size as you may find that they shrink a little as they dry. If you leave 5 to 10mm of circumference it will only take a fairly short time to finish it off the next day. While it is drying, you can start on another one. You will find that you can finish one of Jupiter's moons with two to four hours of pasting.

The final layers

When the ball is at its final size I carefully placed two or three layers of clean white paper. Rather than stacking the paper on randomly, I placed each piece neatly next to each other and minimised any overlapping. This will give a well-defined surface that will show up any major irregularities in the surface. Whilst the occasional dip or bump won't really matter that much, you will now be able to see that some parts of the ball have some major mountain ranges. After the white layer has had at least two days to dry, I gently sanded any obvious high spots from the surface using some 80-grit sandpaper. The white paper will easily show where the valleys between high spots remain. Continue to sand the surface until you are happy that it has a relatively smooth surface. Don't go overboard however and simply remove the entire white paper layer.

Now you will have a layer that is part newspaper and part white paper with peeled bits of paper over the surface. Carefully apply a couple of layers of white paper again, as before, with minimal overlapping. This time you should get a surface that is quite smooth.

Figure 5. Placng the final white layer, some are already completed.

Covering Jupiter's moons

To make the models of Jupiter's moons we will need to print out the gores I mentioned earlier. The files come as PDF documents, but I found it very difficult to print them out in the sizes I required. Eventually I discovered a technique that seemed to work very well.

Even the smallest gores (Io and Europa) will only fit one hemisphere on a single A4 page, the other two require A3 pages. Open the file in Acrobat Reader and ensure the zoom scale is quite detailed, I chose 150%. When you copy the image to the clipboard, it will save it in the resolution shown on the screen and if it is not detailed enough, you will get a very poor quality printout. I used version 9.2 for my processing, but I know the selection tool required may not be available in older versions, so you may need to update it. From the "Tools" menu, choose "Select & Zoom" and then the "Snapshot tool". Now carefully select the top left corner of the first gore on the file and drag over the image (holding down the left mouse button while dragging it over the image). A box will be drawn around the image as you drag the mouse. Release the mouse when you have selected a single gore, making sure you haven't missed any of it. You will then be presented with a dialog box to indicate that the selection has been copied to the clipboard. Now open a new document in Word and paste the clipboard into the page (<Ctrl>V or "Edit" "Paste"). The first gore will now be on the page ready for printing.

Getting the correct size will take a few attempts so you may want to do a couple of proofs in black and white first until you are happy with the size. Print the current page out, I did not use a bubble jet printer for my copies as I was going to cover it with several coats of clear water based varnish and this may dissolve or blur an image from a bubble jet. I used a colour laser jet for my copies and had no problems with smudging. Now you will probably need a calculator to work out the scaling to apply to get the correct size. Measure the circumference of your finished ball, say you are doing Europa and have a final size of 310mm. This gives a half circumference of 155mm. Carefully measure the length of one of the meridians on the print; it will probably be undersize so it may measure 124mm for example. This means you will need to scale the print up by 155/124 = 1.25 times. With the right mouse button, click on the image and select "Format picture" from the popup menu. Select the "Size" tab sheet and note the current scale applied to the image. For example, this may show a scale of 58% at the moment. You will need to increase this scale by the amount we have just calculated, so 58% x 1.25 = 72.5%. Unfortunately, you cannot select fractional scales so round it to the nearest size, say 72%. You may also need to adjust the margins on the paper to fit the whole thing on the page; I set my margins to 5mm on each side to give me the greatest flexibility. Now print the image again and check the measurement. If you are happy with the size, make a full colour copy.

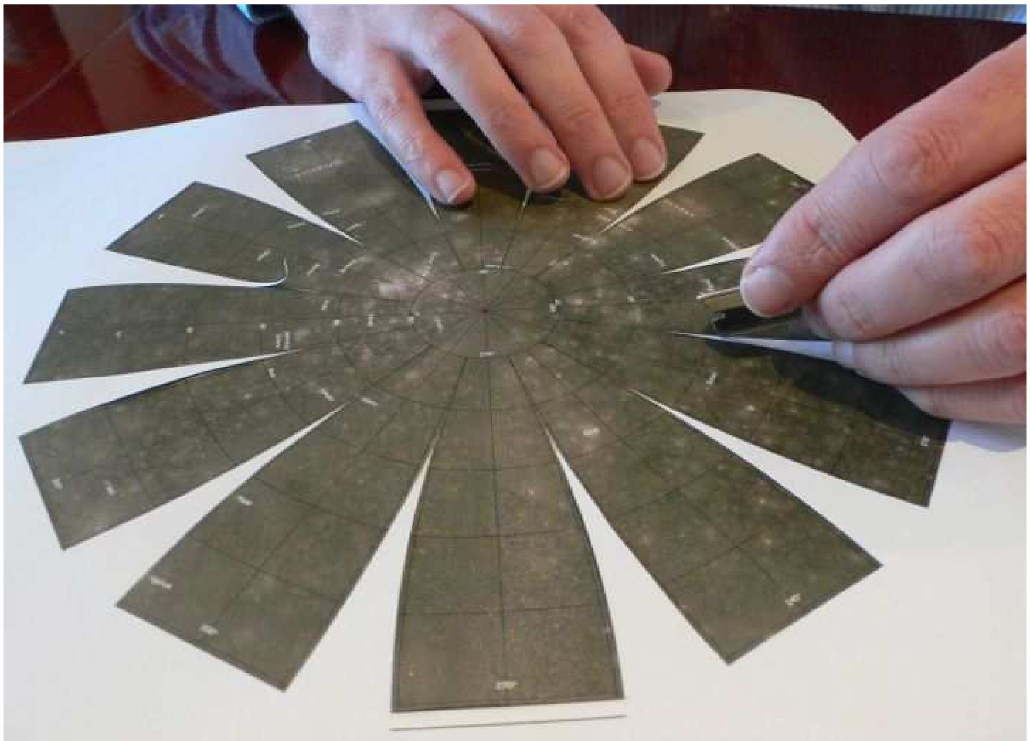


Figure 6. Cutting out a gore.

You are now ready to carefully cut the first gore out, don't be tempted to use scissors unless you are very proficient in their use as you will get ragged edges. The best way to achieve a smooth cut is to use either a scalpel or single sided razor with a cutting board as a base as this will allow a smooth cutting action. With a little practise I was able to cut neatly along the edge of each of the petals without leaving a white border. When you have finished cutting around the gore, carefully pull it away from the paper, taking care not to tear anything. You will notice that the gores have a line that continues from where the wedge of paper runs out to a circle around the pole of the moon. Carefully run the blade along the length of the line, if you don't, you will get very bad creasing of the paper.

The next stage is to begin sticking the gore down to the surface of the sphere. I found Bostik BluStick was ideal for this job. It is blue when you put it on, so you can see if you have missed anything, but sets clear. Rub the stick around the centre of the gore, out as far as the cuts in the paper, and place it onto the sphere. Press it down firmly to the surface. Now lift several of the petals off the surface of the sphere and rub a triangle of glue under where one of the petals will sit and carefully, and gently, press the petal onto the glue trying to keep creasing to a minimum. You will find however that you will still get some creasing but with some careful manipulation it can be minimised. You will need to ensure that all of the edges of the paper are firmly stuck down. I found I could scrape a small amount of glue off the stick with the bent end of a paper clip. This could then be used to poke the glue under any areas that do not have any glue and allow you to stick the whole thing down firmly. Once the first petal is glued, choose the next one along and rub another triangle of glue under where the gore will stick, being careful to keep if off the glue and to not let the other gores become stuck. You will probably find that some areas near the top will be very difficult cover with glue. I used the single sized razor to scrape a small amount of glue from the side of the glue stick and rub it onto any areas I could not reach with the stick. Now carefully glue the petal down as before, being careful that it aligns with the first one. Each of the gores has a small overlap area that will make the alignment much easier. Slowly work your way around the globe and when you have finished, check that all of the edges have been stuck down. The paper clip will come in very handy for making finishing touches to the edges. When you are happy with the finish, leave it to dry for at least a day otherwise you risk getting glue on your fingers and ruining the whole thing if you try to mount the second half in the same day.

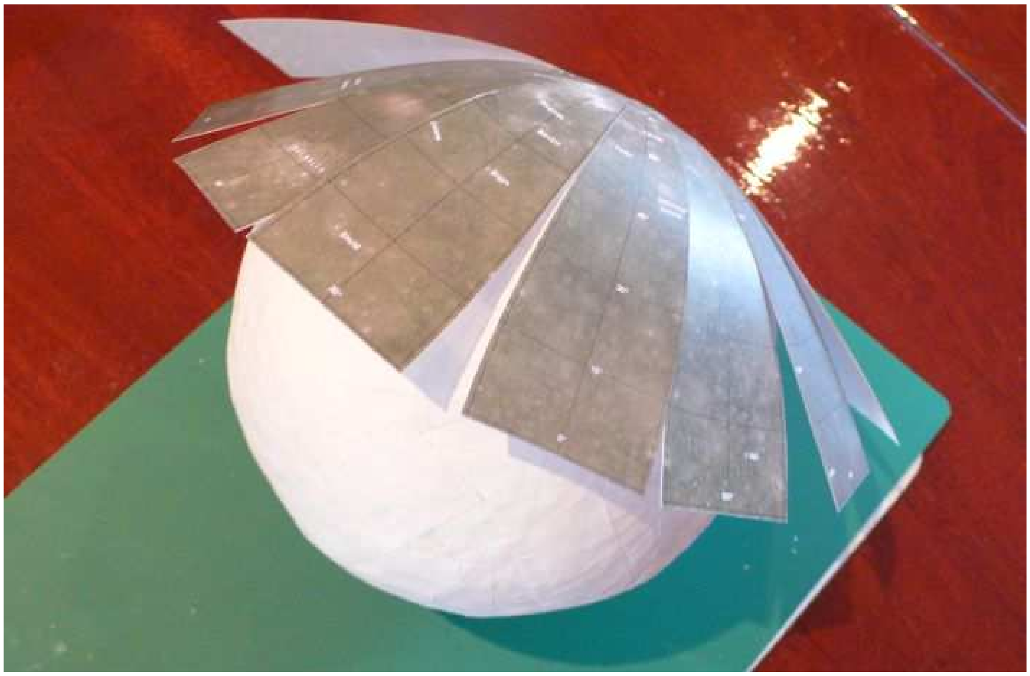


Figure 7. The finished gore is mounted and ready for gluing.

When the first gore has thoroughly dried, carefully measure the distance around the globe from one side to the other. This is the size you will require for the second gore, it is unlikely that the sphere will be perfectly round, so don't be surprised if the second half of the circumference is a couple of millimetres different to the first half! Follow the same procedure again to create the second gore and scale the print out to the required size and cut it out. Before beginning to glue it down, check that it is the correct size and that all of the petals will reach down to the end of the corresponding petal from the other side.

Before gluing the second hemisphere there are a couple of very important points to ensure. Firstly, make sure that you join the petal for the zero meridian to the zero meridian of the first gore, they have angles marked near the poles. Once you glue the centre down to the sphere, make sure that all of the petals reach all of the way around. The first time I put the second gore on, I was almost finished when I realised that I had it tipped to one side and although most of them were ok, by the time I got half way around, they no longer reached and I had to tear the whole thing off, print out a new one and start again.

Figure 8. The finished globe of Ganymede and the soccer ball used as a base.

Once both gores have been glued into place, check around the edges of all of the petals and stick them down firmly. This will give a relatively smooth finish to the whole thing, but I found it impossible to remove all creases or to get perfect alignment of features and grid lines.

To give it a smooth shiny finish, I gave each one several coats of a water based clear coat. I held each one on a small glass bowl to allow me to paint half of the surface easily without making a mess or having it roll around the table. The first coat was made from top to bottom or north to south, then I turned it upside down and painted the other side in the same direction, south to north. A second coat was applied at right angles to the first one, east to west, by placing the globe on its side and painting half of the surface. Finally a third coat was applied again from north to south. This gave a smooth even coat and ensured any visible brush strokes were minimised.

Figure 9. Completed moons of Jupiter.

Finishing off the other planets and moons

Now what about globes for which there are no gores? Titan was easy, I painted it with a yellowish coloured paint, however my first attempt was far from successful. When the paint dried it looked like a ball that was covered with strips of paper and painted yellow. After some thinking, I struck upon the idea of covering the surface with tissue paper. The paper would be so thin that you would not see any edge and you can easily tear it into irregular shapes so there will be no definite edge to each of the pieces of paper. So I carefully tore several tissues into pieces. Dipping the tip of your finger into paste allowed you to easily pick up a single piece of tissue and carefully place it onto the surface. Unfortunately, it is virtually impossible to place the paper onto the surface without creating a number of wrinkles and creases as the paper is so thin and fragile that it will tear with the slightest touch once it is placed onto a glued surface, however, this turned out to be an excellent way of producing a surface that looks more like a series of clouds or mountain ranges and hid the individual pieces of paper better than I could have possibly imagined. When the paper dries you will have a surface that shows no signs of the paper strips hidden below, provided you place two or three layers of tissue over the whole globe. I found I could also create some craters in the surface by carefully rubbing the end of a screwdriver handle or other rounded tools into the surface.

After allowing the paper to dry for a day or so, you can select a suitable colour water base paint and cover it in a couple of coats. Finally give it three coats of clear as discussed with the gores.

Your scale model planet or moon is now complete! The next task is to work out how to mount them in some sort of scale model.

Object	Actual diameter (km)	Actual distance Average (km)	Astronomical Units/Lunar Separations	Orbital inclination (degrees)	Scaled circumference (mm)	Scaled diameter (mm)	Scaled distance (m)	Discovery	Period (d or y)	Comments
Sun	1,393,000	0	0	0.0	139,300	44,340	0.0		25d	Star
Mercury	4,879	57,856,000	0.31 to 0.47	7.0	488	160	1,900.0		88d	Planet
Venus	12,104	108,132,000	0.72 to 0.73	3.4	1,210	385	3,600.0		225d	Planet
Earth	12,756	149,492,000	1.02 to 0.98	0.0	1,276	406	4,900.0		365d	Planet
Moon	3,475	388,000	0.94 to 1.05	5.1	348	110	12.8		29d	Moon
Mars	6,794	227,780,000	1.38 to 1.67	1.9	679	216	7,500.0		686d	Planet
Vesta	530	353,268,000	2.15 to 2.57	7.2	53	16	11,600.0	29 March 1807	1325d	Asteroid
Juno	320	399,725,000	1.99 to 3.66	13.0	32	10	13,100.0	1 September 1804	1595d	Asteroid
Ceres	950	413,832,000	2.55 to 2.99	10.6	95	30	13,600.0	1 January 1801	1680d	Dwarf planet
Pallas	560	414,737,000	2.13 to 3.41	34.8	56	18	13,600.0	28 March 1802	1686d	Asteroid
Encke	5	610,000,000	0.33 to 4.11	12.0	0.5	0.16	20,000.0	1786	3.3y	Comet
Holmes	3	774,000,000	2.05 to 5.18	19.0	0.3	0.10	25,500.0	6 November 1892	6.9y	Comet
Jupiter	142,984	777,776,000	4.95 to 5.46	1.3	14,300	4,500	25,600.0		11.9y	Planet
Io	3,640	421,000	1.08 to 1.09	0.1	364	115	13.8	8 January 1610	1.77d	Moon
Europa	3,124	671,000	1.71 to 1.74	0.5	312	99	22.1	8 January 1610	3.55d	Moon
Ganymede	5,264	1,070,000	2.76	0.2	526	167	35.2	7 January 1610	7.15d	Moon
Callisto	4,818	1,882,000	4.82 to 4.89	0.2	482	153	62.0	7 January 1610	16.7d	Moon
Saturn	120,536	1,425,983,000	9.05 to 10.12	2.5	12,054	3,835	46,900.0		378.1d	Planet
Mimas	414	185,000	0.48	1.5	41	13	6.1	17 September 1789	0.94d	Moon
Enceladus	514	238,000	0.61	0.0	51	16	7.8	28 August 1789	1.37d	Moon
Tethys	1,080	294,000	0.76	1.1	108	34	9.7	21 March 1684	1.89d	Moon
Dione	1,120	377,000	0.97	0.0	112	36	12.4	1684	2.74d	Moon
Rhea	1,529	527,000	1.36	0.3	153	49	17.3	23 December 1672	4.52d	Moon
Titan	5,151	1,221,000	3.15	0.3	515	164	40.1	25 March 1655	15.9d	Moon
Hyperion	328	1,500,000	3.87	0.4	33	10	49.3	16 September 1648	21.3d	Moon
Iapetus	1,470	3,560,000	9.18	15.5	147	47	117.1	25 October 1671	79.3d	Moon
Phoebe	212	12,947,000	33.39	151.8	21	7	425.9	16 August 1898	550d	Moon
Uranus	51,118	2,867,760,000	18.38 to 20.10	0.8	5,112	1630	94,3000.0	13 March 1781	84.3y	Planet
Miranda	480	129,000	0.33	4.2	48	15	4.2	16 February 1948	1.41d	Moon
Ariel	1,162	191,000	0.49	0.3	116	37	6.3	24 October 1851	2.52d	Moon
Umbriel	1,170	266,000	0.69	0.2	117	38	8.8	24 October 1851	4.14d	Moon
Titania	1,578	436,000	1.12	0.3	158	50	14.3	11 January 1787	8.71d	Moon
Oberon	1,522	583,000	1.50	0.1	152	48	19.2	11 January 1787	13.5d	Moon
Neptune	49,528	4,492,800,000	29.8 to 30.4	1.8	4,953	1,894	147,800.0	23 September 1846	164.8y	Planet

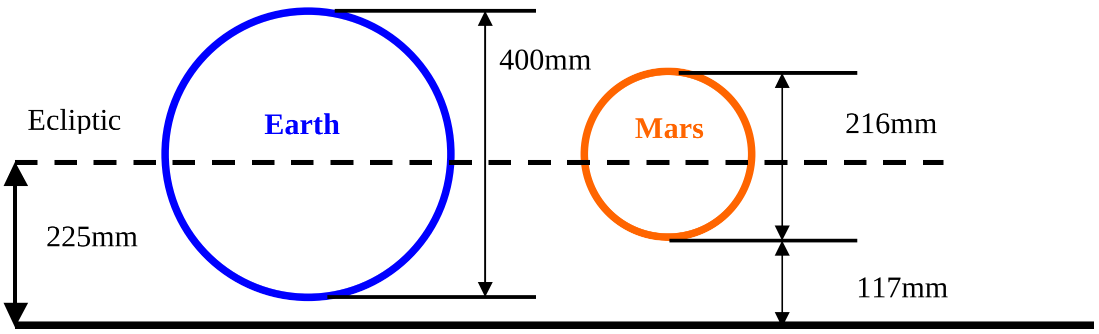
Proteus	436	118,000	0.30	0.5	44	14	3.9	16 June 1989	1.12d	Moon
Triton	2,706	355,000	0.91	129.6	271	86	11.7	10 October 1846	-5.88d	Moon
Halley	11	5,200,000,000	0.59 to 35.1	18	1	0.40	170,000.0		75.3y	Comet
Pluto	2,390	7,375,000,000	29.7 to 49.3	17.1	239	76	245,800.0	18 February 1930	248.1y	Dwarf planet
Charon	1,210	17,000	0.04	0.0	121	39	0.6	22 June 1978	6.39d	Moon
Rhadamanthus	200	5,840,000,000	33.2 to 45.1	12.7	20	7	194,700.0	17 April 1999	245y	TNO
Teharonhiawako/ Sawiskera	176 120	6,570,000,000	42.9 to 45.2	2.6	18 12	6 4	224,500.0	20 August 2001		Binary TNO, KBO
Quaoar	800	6,716,000,000	41.9 to 45.3	8.0	80	26	224,000.0	5 June 2002	288.0y	TNO, dwarf planet
Varuna	800	6,781,000,000	40.9 to 45.3	17.2	80	26	226,000.0	28 November 2000	283.2y	KBO, dwarf planet
QB1	160	6,976,000,000	40.9 to 46.6	2.2	16	5	232,000.0	30 August 1992	289.2y	QB1
Deucalion	211	6,611,000,000	41.6 to 47.2	0.4	21	7	234,000.0	18 April 1998	295.5y	TNO, QB!
Orcus	940	7,188,000,000	30.3 to 48.1	20.6	94	30	239,600.0	17 February 2004	245.3y	KBO, dwarf planet
Ixion	800	7,370,000,000	30.1 to 49.2	19.6	80	25	245,600.0	22 May 2001	250.0y	TNO
Chaos	560	6,794,000,000	40.9 to 50.3	12.0	56	18	249,800.0	19 November 1998	309.1y	KBO, QB1
Huya	530	7,627,000,000	28.5 to 51.0	15.5	53	17	254,200.0	10 March 2000	250.7y	TNO, red
Haumea	1,150	7,710,000,000	34.7 to 51.5	28.2	115	37	257,000.0	28 December 2008	283.3y	KBO, dwarf planet
Makemake	1,500	7,940,000,000	38.5 to 53.1	30.0	150	48	265,000.0	31 March 2005	309.9y	KBO, dwarf planet
Typhon Echidna	130 78	5,676,000,000	17.5 to 58.8	2.4	13 8	4 3	292,000.0	5 February 2002		Binary SDO
Eris	2,600	14,600,000,000	37.8 to 97.6	44.2	260	83	487,000.0	5 January 2005	557y	TNO, dwarf planet
Ceto/ Phorcys	174 132	14,870,000,000	17.8 to 181.9	22.3	17 13	5 4	903,400.0	22 March 2003	998y	Binary SDO
Sedna	1,400	146,000,000,000	76.2 to 975.6	11.9	140	45	4,867,000.0	14 November 2003	12,059y	TNO, dwarf planet

Table 1. List of astronomical objects and their scaled circumferences and diameters.

Creating a mounting base for the planets

If you look at some of the scaled distances between planets and their moons and the Sun and each of the planets, you will quickly realise that it would be impossible to create a complete scale solar system by using the same scale throughout, the distance to Neptune is 150km let alone the dwarf planets. After thinking about this problem very carefully, I realised that if you simply divide the distances between a planet and it's moons by a factor of 100, you get a scale that is quite manageable. The distance from the Earth to the Moon changes from 12 metres to just 120mm, even Callisto comes from 62 metres down to just 620mm, quite a reasonable distance. The next problem is of course that the distances between the Sun and each planet is even more problematic. The distance between the Sun and the Earth is almost 5 kilometres! Even if I divide this by a factor of 100, as with the moon distances, I still end up with almost 50 metres. However, if I divide this by another factor of 1000, metres become millimetres and the whole thing becomes manageable in this direction, the distance to the Earth is now only 49 millimetres and even Pluto is only 2.5 metres away. So my scale was set, moons are 100 x 30 million or 3 billion to one and the distances between the planets become 100 x 1000 x 30 million or 3 trillion to one. I also applied the same reduction to the size of the giant planets as I applied to the moons, making Jupiter just 45 millimetres in diameter. This also has the advantage that the positions of their moons are seen in the same proportion as the planet on the finished model, so the moons of Saturn are seen the correct distance from it's ring system. Only a small number of objects on the model are at such a large distance that they don't fit on the model area even at the reduced sizes. Sedna is situated more than forty metres past the end of the finished model.

Of course, I needed a way of holding the objects onto the base of the model without obstructing them from clear view and so came up with a couple of different methods of mounting them. To hold the larger models, I cut out rings from stormwater pipe and attached legs onto the sides to hold them. To get all of the planets aligned in the same plane I needed to measure the diameter of each one and calculate how high they needed to be held up in order for the centre to align with the centreline of the Earthball. If any object is located at a high inclination to the ecliptic, I would need to add an extra height to place them the required distance above the plane of the ecliptic. So with a diameter of 400mm, the centreline of the Earth sits 200mm above the "south pole". I placed the Earth on a stand that would lift it 25mm off the mounting surface and so the "ecliptic" on the model sits 225mm from the surface. With a diameter of 216mm, the centreline of Mars would need to be placed 117 millimetres higher than the Earth:



200 + 25 – (216 / 2) = 225 – 108 = 117 millimetres

So the stand for Mars would need to be 117 millimetres high, compared to 25mm for the Earth. For my calculations, I have assumed that very little of the bottom part of the ball is actually below the supporting ring, in the worst case they sit about 10mm below the ring and in most cases much less, which is not a major concern in this case.

For the smaller objects a simpler method of mounting was needed as there are many more smaller models to be mounted and their smaller size did not required 3 points of support. I machined a piece of black plastic to a little larger than the diameter of the object and drilled a 10mm hole in the base. I then glued a piece of clear acetate around the perimeter of the plastic base, creating a cup to place the ball into. This gave a way of holding the object without it falling out easily and yet remains clearly visible. I cut a single piece of wooden dowel to the size required to place the centreline of the object at the correct height above the mounting surface.

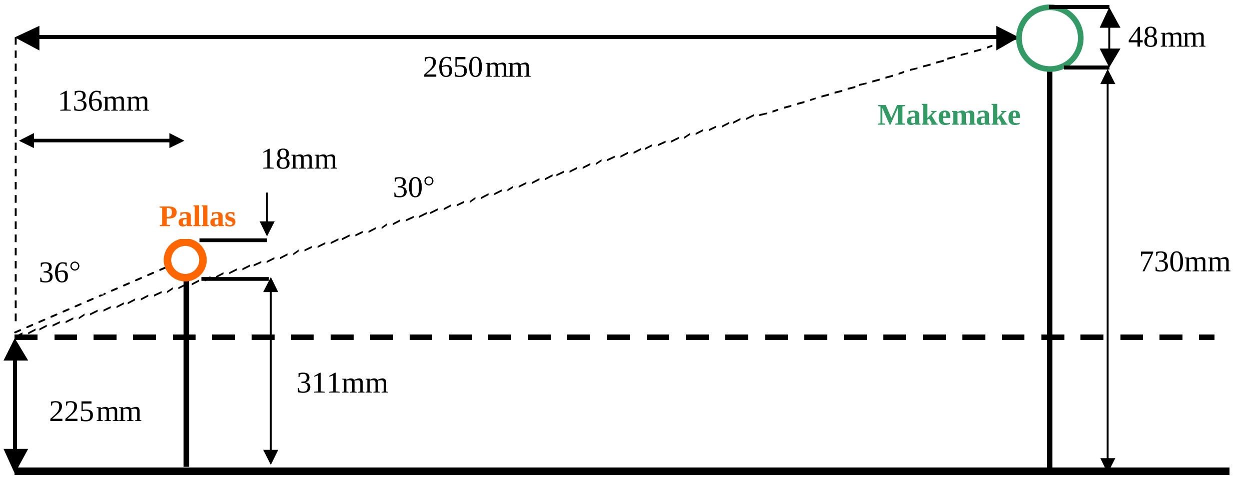
All of the largest planets are at a very small angle to the ecliptic and so I didn’t bother to apply any correction for this. However, for the asteroids and all of the minor planets this is not the case and some correction is needed to make the model truly representative of reality. Thus the calculation of an extra factor was required in these cases. The asteroid Pallas sits at an inclination of 34.8 degrees. At a scaled distance of 136mm from the Sun, this gives a correction of:

136 x tan(34.8) = 136 x 0.7 = 95.2mm higher than the centreline.

With a diameter of just 18mm this means the top of the mounting base needs to be:

225 + 95.2 – 9 = 311.2 millimetres

above the supporting base. As the distances get greater, the extra heights become quite large, even at modest inclinations.



With an inclination of 30 degrees and a distance from the Sun of 2.65 metres, the corrected height for Makemake becomes:

225 + (2650 x tan(30) – (48 / 2)) = 225 + 1530 – 24 = 1730 millimetres!

After many hours on the calculator I created the corrections for all objects requiring one. When the whole model was finally assembled I had created a number of stands, the biggest being more than 2 metres in length.

Finally I created a method of making a long timber frame of more than 2 metres in length that folds into quarters and easily fits into the back of my car. A larger area is needed to hold the larger planets and moons which was built in the form of a large table area with lines marked for each planet's distance from the Sun and the distance to their major moons. The whole model breaks down to a few large parts that can be placed on top of each other and a couple of boxes carry most of the planets and other objects. A couple of bags hold the stands and keep them from becoming dusty or mislaid. It becomes immediately obvious from the model why Triton is not a "normal" moon and why the objects from around Pluto and beyond do not fit with the rest of the solar system.