Chapter 4

Megaworld

1 000 000 (1.0 x 10^6) M

4.1 Megaworld Length

1 – 1000 Megameters (Mm) 1 x 10^6 m

Distances along the surface of planet Earth are conveniently expressed in Megameters. The maximum distance between any two locations on our planet is very close to 20 Mm. The original definition for the meter was to be a length such that the great circle distance around Earth would be 40 Megameters (40 000 Km). When one describes continental dimensions, one immediately encounters values in Megameters.

The Inland Customs Line was a barrier build across India by the British to collect a tax on salt. The line was initiated while India was under the control of the East India Company, and was maintained when the British took direct rule of the country. The continuous barrier was created to stop the smuggling of salt so as to avoid the salt tax. Previously, the boundary was made of separate sections which could be avoided by smugglers.

The British began to create a hedge as a barrier that would become known as the Great Hedge of India. By 1868, the "thoroughly impenetrable" hedge was 290 Km long, requiring constant maintenance. The line was slowly enlarged and eventually tra-

Megameter Lengths

Example	Length
The Great Hedge of India	1.3 Mm
Point Nemo	2.668 Mm
Diameter of the Moon	3.47 Mm
Length of First Transatlantic Cable (1866)	4.2 Mm
Diameter of Mercury	4.88 Mm
Lewis & Clark Expedition	6 Mm
Great Wall of China	6.3 Mm
Circumference of the Moon	10.9 Mm
Earth's Antipode Distance (through Earth)	12.74 Mm
Longest Single Continuous Line One Can Sail on Earth	20 Mm
Great Wall of China (with all its branches)	21.2 Mm
Length of Telegraph Wire Strung by Union Engineers	24 Mm
Length Light Travels in the Blink of an Eye	30 Mm
Wavelength of Schumann Resonance	38.314 Mm
Earth's Circumference	40 Mm
Joshua Slocum's Solo Circumnavigation of the Earth	74 Mm
Combined Length of Roman Roads	80 Mm
Ben Carlin's Amphibious Vehicle Circumnavigation	81 Mm
Total Length of Human Blood Vessels	100 Mm
Distance an Average Person Walks in a Lifetime	120 Mm
Apollo 11	770 Mm
Length of The Earth's Shadow	1400 Mm
Arctic Tern's Lifetime Migration Distance	2400 Mm

Table 4.1: Megameter Illustrative Examples

versed a length of 4 Megameters (4 000 Km). The original barrier was constructed of dead thorny vegetation. Ultimately it was transformed into a living hedge which was up to 3.7 meters high, and 2.5 meters thick, this is thought to have begun about 1840.

The hedge consisted of multiple types of vegetation, depending on the soil and climate, including Indian plumb, babool, and where no other plant would grow, prickly pear. They had to experiment with numerous thorny shrubs and planting methods to see what would grow. Landscaping was undertaken to channel water from

Figure 4.1: Route of the Inland Customs Line which incorporated The Great Hedge of India – Wikimedia Commons

rain where it was dry, and divert it away from land that was wet. Sections of the hedge required constant replacement of vegetation. The amount of labor to maintain the hedge was colossal. At its peak, 14 188 men were responsible for tending the hedge. It had 1800 customs posts along its length manned with almost 10 000 men. They collected the salt duty from all those who crossed the line.

Almost before it was completed, British officials began to consider abandoning the Great Hedge of India. From 1869 to 1872,

British officials began negotiating agreements with the states in the regions to assure monopoly control of the area. Smuggling no longer made economic sense, which made The Inland Customs Line, and its Great Hedge, redundant. The line was abandoned on April 1st 1879.

The Inland Customs Line and its Great Hedge of India, despite the fact it was a Herculean undertaking, was quickly and almost totally forgotten, and was little mentioned in histories of the period. In 1995, Roy Moxham, a conservator at the University of London Library, was visiting a used book store in London, and came across a book called *Ramblings and Recollections of an Indian official*. The book contained a footnote, which mentioned the Inland Customs Line, and that a majority of it consisted of an impenetrable hedge, and was in total over 4 Megameters (4 000 Km) in length. This length is longer than the diameter of the Earth's moon.

Moxham had been to India many times, and had never heard about this barrier. He was very skeptical. The hedge would have existed within the living memories of many grandparents, yet no one talked about it. After considerable research, Moxham was able to confirm its existence. It was only in 2001, when Roy Moxham, published a book titled *The Great Hedge of India* detailing the history of the Inland Customs Line, and his quest to locate its remains, that the hedge was restored to collective memory. Moxham located a small raised embankment, which may be the only remains of the Great Hedge, which traversed over four Megameters in extent.

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The location on the surface of the Earth's ocean, which is the farthest from any land, is called the oceanic pole of inaccessibility; it is also known as Point Nemo. It is located 2.668 Megameters (2 668 Km) from the closest land. Figure 4.2 gives the location of Point Nemo, with a circle drawn around the landless expanse of ocean surrounding it. The diameter of this circle is 5.34 Megameters.

Point Nemo is a popular target for the disposal of spacecraft. It is a location where few people would attempt to explore or salvage the space junk which has been guided there, or could be injured by the incoming fragments. The use of Point Nemo as a location to position end-of-life spacecraft began in 1971, and is the favored location for their demise. Perhaps the largest item of space trash which crash-landed near Point Nemo was the 130 Megagram Russian Mir Space Station. This happened on March 23, 2001. The Chinese lost control of their 8.5 Megagram Tiangong-1 Space Station in 2016, and after four years of failing to regain control, sent it to the Point Nemo Spacecraft Cemetery in 2018. Since 1971, over 260 spacecraft have met their end near Point Nemo, and have come to rest about three Kilometers below the surface of the Pacific Ocean.

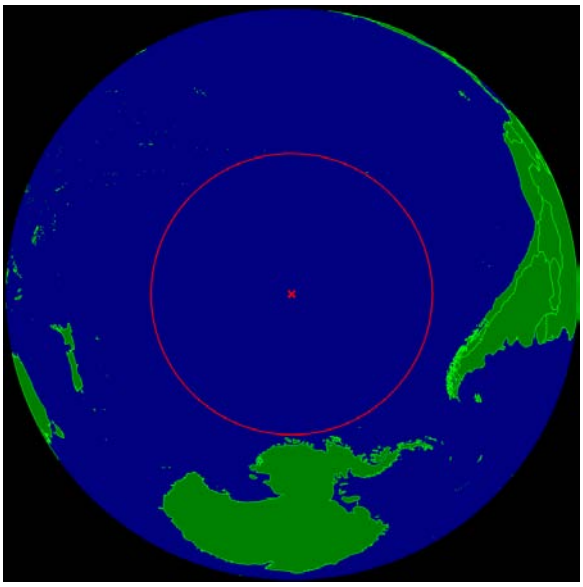

Figure 4.2: Location of Point Nemo, the spot in the ocean farthest from any land (Wikimedia Commons)

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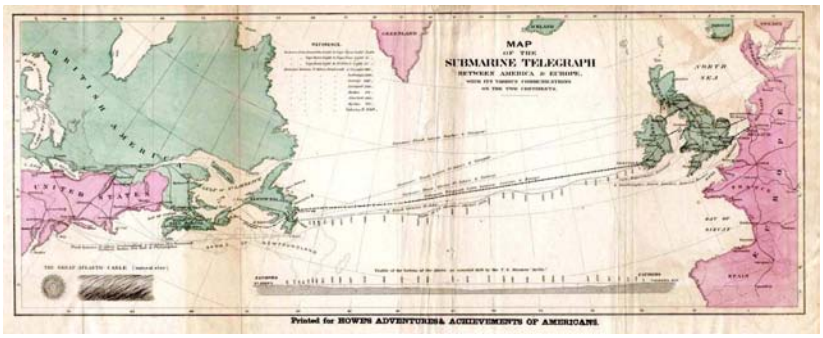

Figure 4.3: Route Proposed in 1858 for a transatlantic cable.

In the 19th century, there were a number of attempts to lay a telegraph cable across the Atlantic Ocean from North America to Europe. (See Figure 4.3) The first four attempts failed, but on Friday, the 13th of July, 1866, the *Great Eastern* set sail from Valentia Ireland for a fifth try.

The *Great Eastern* was the most massive ship of its day. It was designed by visionary engineer Isambard Kingdom Brunel (1806-1859). The *Great Eastern* was without question the largest ship ever built when it was launched in 1858. It was five times larger than any other vessel afloat, with 225 Gigagrams displacement. It had been designed to carry 4000 passengers non-stop from England to Australia. This is about twice as many passengers as the Queen Mary could carry when it was launched 77 years later. With a capacity of 13.5 Gigagrams of coal on board, it could steam around the planet without need for refueling. The 211-meter-long vessel proved to be ideal for laying down a transatlantic telegraph cable.

On the 27th of July 1866, the *Great Eastern* arrived in Newfoundland, and the next morning the end of the 4.2 Megameter long cable was carried ashore. When tested, it was found to be in perfect working order. North America and Europe have never been out of immediate communication ever since.

Copper telephone wires were installed in the 1950s, and fiber

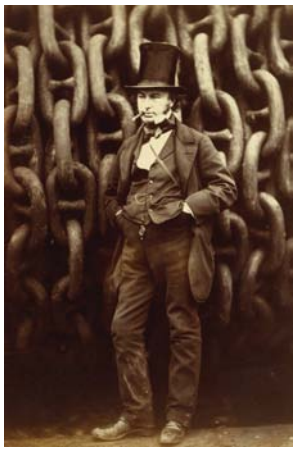

Figure 4.4: Isambard Kingdom Brunel photographed against the launching chains of the *S.S. Great Eastern* in 1857 (Robert Howlett).

optic cables spanned the two continents in the 1980s. The original transatlantic cable was long enough (4 200 Km) one could, in principle, drill a hole through the center of the Moon, pass the cable through it from the Earth-facing side to the antipode on the "dark side" of the Moon,* and establish a telegraph link.

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The Lewis and Clark expedition travelled a distance of approximately six Megameters (6 000 Km).

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The Great Wall of China has a length of 6.3 Megameters. This pre-industrial engineering marvel is longer than the diameter of Mercury (4.88 Mm) or the Moon (3.47 Mm). The Great Wall of China is a misnomer, there have been at least 16 different sets of walls. The first ones were erected in the 8th century BC and the last in the 17th century. The best known of these is the Ming

*There is no "dark side of the Moon." All sides of the Moon receive sunlight but because the Moon is tidally locked, it shows only one side to the Earth. The other side is dark only in the sense that we never see it from Earth.

Great Wall, constructed during the Ming Dynasty (1368-1644). The wall itself is 6.259 Megameters in length, but it also incorporates 2.591 Mm of natural geographic barriers for a total effective length of 8.85 Megameters. It is estimated up to 25 000 watchtowers existed along its length. The Great Wall is so long, guards occupying the towers at the East end of the wall experienced sunrise one hour and twenty minutes before those at the West.

A recent archaeological survey measured the entire wall with all its branches and the total is 21.196 Megameters. This is half way around the circumference of the Earth, or more than the length from the North Pole to the South Pole. The amount of stone used for The Great Wall could be used to construct a 2 meter high wall along the equator of the Earth, separating the Northern and Southern Hemispheres.

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If a person could construct a room at the center of the Earth, they would be weightless. The gravitational pull would be essentially equal and outward with 6.371 Megameters of planetary material in every direction.

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When we stand on the Earth's surface, there is a place directly opposite of us on the other side of the planet, which is called an *antipode*. Antipode is from the Greek word antipodes meaning "with feet opposite (ours)." In medieval Europe, a belief in the existence of antipodes could be considered heresy, as there were authorities who asserted the entire Earth was flat. L. Sprague de Camp relates this compromise:

> . . . Some thinkers of the early Middle Ages seem to have been convinced by arguments in favor of the spherical earth but felt unable to accept the idea of the antipodes. Possibly influenced by the round landmass of the earliest Greek thinkers they succeeded in combining the round oikoumenë, the spherical earth, and the nonexistance of antipodes into one. They postu-

> lated that the world consisted of two spheres, one of land and one of water. If the two were perfectly concentric all land would be covered by water, drowned in a shoreless ocean. But if the two spheres were not quite concentric a circular island would appear above the water: the known inhabited world. The question of the antipodes then ceased to exist, for on the other side of the earth the ocean would be deepest. [1]

Modern misconceptions about antipodes remain. One which was a trope in children's cartoons, was the idea that if a person were to dig a tunnel through the Earth from a surface location inside the continuous 48 states, they would arrive in China. This notion is proverbial enough, that the 1979 movie *The China Syndrome*, about the meltdown of a nuclear power plant, conjured up the idea that if the core continued to melt through the bottom of its containment vessel, the radioactive molten mass would pass through the Earth until it surfaced in China.

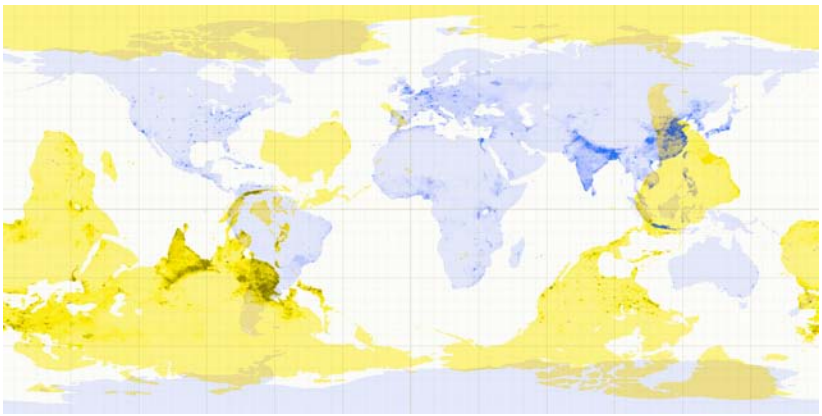

Figure 4.5: Antipodes map – Wikimedia Commons

An antipodes map of the Earth is shown in Figure 4.5. What is immediately obvious, is that no significant amount of land exists below the 48 states. If one dug a tunnel through the Earth, they

would surface at the bottom of the Indian Ocean. A small sliver of Alaska is across from Antarctica. Persons living in Hawaii would find themselves in Africa, in the country of Botswana or Namibia. Only areas of South America have antipodes in China. The antipode distance for the Earth is 12.742 Megameters (12 742 Km). This is about twice the length of the Great Wall of China. If a person travels 20 Megameters in *any* direction along the surface of the Earth, we end up at the antipodal point from where we originate.[2] The north pole and south pole are antipodes.

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If one views the Earth's moon from the northern hemisphere, say Denver, Colorado, and then moves to the southern hemisphere, say Melbourne, Australia, the moon's image will be upside down in Australia, when compared with the view from the US, and vice-versa.

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The longest straight continuous line one can sail on the Earth is approximately 20 Megameters. This line runs from Pakistan to the Kamchatka peninsula in Russia, and is about half the circumference of the Earth. The two locations are essentially antipodes.

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During the US Civil War, communication became of paramount importance for logistics. The Signal Telegraph Corps of the Union Army had strung 24 Megameters of telegraph wire by the end of the war. The telegraph lines were eventually made of copper wire, and to protect this logistical asset from the elements, coated with vulcanized rubber. They were then protected by Union cavalry patrols.[3]

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The average eye blink is thought to be about 100 milliseconds. Light travels at 300 Mm per second. Therefore light travels 30 Megameters, or three-quarters of the distance around the Earth's equator in the blink of an eye. Some eye blinks can take up to 400

milliseconds. Light travels a length equivalent to three times the distance around the Earth during a long eye blink.

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The Earth and its upper atmosphere form a spherical electromagnetic cavity. The upper atmosphere is one conducting shell, and the ground forms a second concentric conductive shell. Between these two surfaces, an electromagnetic cavity exists.

In 1952, German physicist Winfried Otto Schumann (1888–1974) put forth a theory which predicted lightning strikes should drive electromagnetic cavity resonances within this volume. They are called Schumann resonances after their discoverer. Lighting strikes the Earth between 50-100 times per second.

The fundamental, or lowest frequency mode, of the Schumann resonances, produces a standing electromagnetic wave with a wavelength approximately equal to the circumference of the Earth. The frequency of the first Schumann resonance is 7.83 Hertz. This means the electric field of the wave fluctuates from maximum to zero and back to its maximum 7.83 times per second.

In the early 1960s, two researchers, Balser and Wagner, measured and confirmed the existence of Schumann resonances. The measured frequency of the fundamental resonance corresponds to a wavelength of 38.314 Megameters. The measured wavelength is smaller than the measured value of the Earth's circumference, because water vapor and other materials in the air lower the frequency of the resonance, and therefore its wavelength.

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The distance around the Earth is 40 Megameters.

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Joshua Slocum (1844-1909) was the first person to sail around the Earth alone. Slocum began his circumnavigation of the Earth when he was 51 years old, in his 11 meter oyster boat, *Spray*. Between April 24th, 1895 and June 27th 1898, he crossed the Atlantic Ocean twice, passed through the Straight of Magellan, crossed the Pacific Ocean, visited Australia and South Africa, and

again crossed the Atlantic before arriving in Newport, Rhode Island. The length of his journey was 74 Megameters. Slocum published an account of his odyssey in 1900. On November 14th, 1909 Slocum set sail for the West Indies, and was never seen again. Despite his long-time experience as a mariner, Slocum never learned to swim.

Engineer Ben Carlin (1912-1982) was the first person to circumnavigate the Earth with an amphibious vehicle. He customized a Ford GPA "Seep," an amphibious version of a Jeep, that can travel on both land and water, which he dubbed the *Half-Safe*. The inspiration for the name *Half-Safe*, was a marketing slogan for Arrid, which is a brand of deodorant: "Don't be half-safe use Arrid to be sure." Carlin began his journey in 1948 with a number of false starts, and invested another 10 years of effort, but finally finished in Montreal Canada on May 10th 1958. Carlin and his part-time companions traveled over 17 Megameters by sea, and 62 Megameters by land, for a grand total of 80.524 Mm (80 524 Km), or over double the circumference of the Earth.

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The combined length of all the Roman roads built to maintain their empire is about 80 Megameters, or twice the distance around the Earth. Some Roman roads were up to ten meters in width.

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The Arctic tern spends the summer in the Arctic, and then avoids the Arctic winter by flying to the Antarctic. After the Antarctic summer, it again migrates back to the Arctic. On its journey, it spends 7 months of the year traveling, and at each pole experiences 2 1/2 months of continuous sunlight, and more total daylight than any other creature on the planet.[4] The maximum distance clocked for their round-trip migration is about 90 Megameters!—(90 000 Km). The migration of the Arctic Tern is by far the longest known in the animal world. The Arctic tern is about 350 mm in length, with a wingspan of about 700 mm. During its lifetime, an Arctic Tern can traverse over 2400 Megameters, which would be over three trips to the moon and back. Arctic

terns generally migrate far enough from shore they are seldom seen from land when it is not breeding season.

Figure 4.6: Arctic Tern in Flight – Wikimedia Commons

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An average person walks the equivalent of three times around the Earth in a lifetime, or about 120 Megameters.

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When Apollo 11 landed on the Moon, Neil Armstrong, Buzz Aldrin, and Michael Collins (who remained in orbit) had traveled about 385 Megameters. The Astronauts of the Apollo lunar missions during the 1960s and 1970s traveled the farthest from the Earth any group of humans have ever experienced. That said, the round trip was still in the Megameter range.[†] Megameters are a useful length for describing planets, and are the transition from

[†]Pieces of fabric and wood from the original Wright Flyer were taken to the Moon by Apollo 11 and so also made the 770 Megameter journey.

units we can experience in everyday life, to those which are truly astronomical. When we enter Gigaworld, the dimensions and distances will no longer be understandable in any everyday sense.

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Each day, our position on the Earth rotates into its shadow side, and day becomes night. The shadow of the Earth is conical in shape and extends about 1 400 Megameters beyond the Earth's center, opposite the Sun. At 385 Megameters, the approximate distance from the Earth to the Moon, the conical shadow has a diameter of about 9.33 Mm. The Moon's diameter is only 3.48 Megameters, so the Earth's shadow at this position is about 2.7 times wider. When the Moon passes through this shadow, it produces a lunar eclipse which covers the Moon in darkness for up to an hour and a half.

The Moon also casts a shadow, but its cone of darkness only extends about 377 Megameters, where it forms a point. The Earth's center is about 384 Mm from the Moon's center. This means when the Moon is directly over the Earth, with the Sun behind it, the Moon's shadow point does not quite reach the Earth's surface. The Moon's shadow disperses before it is within 1.36 Megameters (1 360 Km) of the Earth's surface. Considering the distances involved, the Moon's shadow just barely comes short of the Earth. If one is at the location on Earth below where the Moon's shadow is a point, and looks toward the Sun, the Moon concentrically covers the Sun's disc. At the Earth's surface, the Moon will appear slightly smaller than the Sun, and sunlight will equally flood around the darkened Moon. This is not a total eclipse, but a partial one, which is called an annular eclipse. An annulus, or ring of glistening light, is seen to surround the black disc of the Moon.

If the Moon's shadow is 1 360 Km above the Earth's surface, then how can one see a total eclipse? The values provided were average values, and the Moon does not move around the Earth in a perfect circle; likewise, Earth's orbit isn't perfectly circular around the Sun. They move in ellipses, sometimes closer to the parent body (periapsis) and sometimes further (apoapsis). The

apparent sizes of the Sun and Moon change because of this, larger when closer to the viewer, and smaller when further away. The position of the Moon's shadow point also changes, and as the Moon is at its closest distance from Earth, the point at the end of the Moon's shadow is also at its nearest. When it is nearest, the point at the end of the Moon's shadow reaches the Earth's surface, and creates a circular shadow. This is how it is possible to have a total eclipse of the Sun, especially if Earth is also at its apoapsis and the Sun is slightly smaller than usual in the sky. The maximum width of this shadow (also called an *umbra*, from a Latin word meaning "shade" or "shadow") is 268 Kilometers. This umbra covers about 54 000 square Kilometers of the Earth's surface (about twice the size of Massachusetts).

When all is favorable, the Moon begins to cover the Sun, and produces a partial eclipse. Just before the Moon covers the last of the Sun's light, a number of beads of sunlight are seen. These are known as Baily's Beads after Francis Baily (1774–1844), who was the first to explain the phenomenon. When a single bead is left, it produces a dazzling diamond like flood of light with a luminous ring. This is called the "diamond ring" effect and lasts only a moment. After this last bead of light is extinguished, the corona appears. The total eclipse ends when a diamond appears on the opposite side of the first encounter. Quickly, the flood of light becomes too intense to view, and a partial eclipse returns until the Moon finally passes from view.

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The radii of the planets in the Solar System are given in Table 4.2. One can readily see Mercury is the smallest planet, and Mars is rather small when compared with Earth and Venus. It is immediately obvious why astronomers often refer to Venus as Earth's "twin." It certainly is very nearly the same size as the Earth, but Venus orbits the Sun every 224.65 days and rotates on its axis every 243 days. This means a day on Venus is longer than its year. Venus also rotates on its axis in a reverse direction from Earth and the rest of the planets in the Solar System. Venus has

Radius of Planets in The Solar System

Planet	Radius
Mercury	2.439 Mm
Venus	6.051 Mm
Earth	6.371 Mm
Mars	3.390 Mm
Jupiter	69.911 Mm
Saturn	58.232 Mm
Uranus	25.362 Mm
Neptune	24.622 Mm

Table 4.2: Radii of Solar System Planets

no moon or rings.

One can also immediately see the sudden increase in size from the inner Terrestrial planets, Mercury, Venus, Earth, and Mars, to that of the outer Gas Giants of Jupiter, Saturn, Uranus, and Neptune.

If all the planets, other than Earth, were lined up end to end, with Saturn's rings tilted as to not get in the way,[‡] it would span a distance of about 380 Megameters. Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune could all fit between the Earth and the Moon with about 5 Megameters to spare.

Pluto is now designated a dwarf planet, and is not included in the list. With a mean radius of 1.186 Megameters, Pluto is about half the size of Mercury. In 1978, it was discovered Pluto has a moon, now called Charon. Charon has a mean radius of 0.60 Megameters (604 Km). The radii of Pluto and Charon are close enough to one another they may be viewed as a dwarf-double planet. The two bodies are gravitationally locked, which means the same face of Charon always faces Pluto as they orbit one another. Pluto and Charon revolve around their barycenter every 6.387 days.

[‡]Saturn's rings extend over a range of 7-80 Megameters from its equator, but they are only 10 to 1000 meters thick.

The center of mass about which two bodies orbit in space is called the *barycenter* of the orbiting system. When two orbiting bodies are similar in mass, they orbit about a barycenter located within the space between them. In the special case when two orbiting bodies have identical mass, they orbit about a location which is exactly midway between them. In the case of Pluto and Charon, the barycenter is located almost a Megameter (960 Km) outside the surface of Pluto, or 2.110 Megameters from the center of Pluto.

In the case of the Earth-Moon system, the mass of the Earth dominates, and the barycenter is located 1.710 Megameters *inside* the Earth. The Moon orbits in a large circle around the barycenter as the Earth orbits along a much smaller one.

4.2 Megaworld Area

1 – 1 000 000 Square Megameters (Mm^2) 1 x 10^{12} m^2

The area of the Roman Empire at its largest extent was about 5 square Megameters. In terms of area, it was between Mexico, at 2 square Megameters, and Australia, at 7.74 square Megameters.

The Amazon river drainage basin covers an area of 6.3 square Megameters. This river expels so much water into the Atlantic Ocean, that more than 200 Km out to sea, off of the mouth of the river, one can dip fresh water out of the ocean, that is drinkable.

Areas of the larger countries on Earth are in the ten square Megameter range. The United States has an area of about 9.36 square Megameters, China 9.6 square Megameters, and Canada is 9.97 square Megameters. The largest country in terms of land area is Russia at almost exactly 17 square Megameters (17.098 Mm^2). The surface area of the Earth's moon is 39.73 square Megameters. The maximum visible side of the moon, at any given moment, is about half of this or 20 Mm^2. The area of Russia would not quite cover the near side of the moon. It would take a combination of Russia, Canada, China and the US (46 square Megameters) to

Surface Area of Earth's Oceans in Square Megameters

Ocean	Area
Arctic	14 Mm^2
Southern	20 Mm^2
Indian	69 Mm^2
Atlantic	77 Mm^2
Pacific	156 Mm^2
Total	335 Mm^2

Table 4.3: Megameter Areas

more than cover the Moon's surface (40 square Megameters). The British Empire at its largest extent was 35.5 square Megameters.

The areas of the world's oceans are readily expressible in terms of square Megameters. The surface area of each ocean, and their total, is given in Table 4.3. The total area of the Earth's oceans, in square Megameters, is approximately 335 Mm^2. The ocean surfaces of the world are easily contained within Megaworld.

The total surface area of the Earth (land and ocean combined) is approximately 510 square Megameters. The total surface area of land on the Earth is 149 Mm^2. The amount of land on Earth is so small, that all of the continents on Earth would fit in the Pacific Ocean. Science fiction writer Arthur C. Clarke (1917–2008) once stated: "How inappropriate to call this planet Earth when it is quite clearly Ocean."

The Earth is essentially a double planet, with a moon which has a surface area of 38 Mm^2. If we add the surface areas of the Earth and Moon together, we calculate the surface area of the Earth-Moon system to be only 548 Mm^2. We can bump up the total surface area to 1008 square Megameters by adding in Venus, with its surface area of 460 Mm^2. It takes the surface area of the Earth, its Moon, and Venus to sum up to approximately 1000 square Megameters.

In Table 4.4 we see all the inner planets have surface areas which are well below 1000 square Megameters, and the gas gi-

Surface Area of Planets in The Solar System

Planet	Area
Mercury	75 Mm^2
Venus	460 Mm^2
Earth	510 Mm^2
Mars	140 Mm^2
Jupiter	64 000 Mm^2
Saturn	44 000 Mm^2
Uranus	8 100 Mm^2
Neptune	7 700 Mm^2

Table 4.4: Megameter Areas

ants are much greater than 1000 Mm^2. Jupiter, with a whopping 64 000 Mm^2, is the planet with the largest "surface area" in the Solar System. The two largest planets, Jupiter and Saturn, have a combined surface area of 108 000 Mm^2. The rest of the planets have a combined total of only 17 000 Mm^2.

The gas giants have remarkably huge features, bigger than anything in the inner Solar System, even the rocky Terrestrial Planets themselves. For example, Saturn has a hexagonal shaped cloud formation at its north pole. (See Figure 4.7) This pattern of clouds rotates with a period of 10 hours, 39 minutes, and 29 seconds. Its six sides are each 13.8 Megameters in length. This means each side of this hexagon is longer than the diameter of the Earth (12.74 Mm). The hexagon's perimeter is 82.8 Megameters in length, or over twice the length of the Earth's circumference. The surface area of this hexagonal cloud is 495 square Megameters, which is larger than the surface area of Venus, and approaches that of the Earth. The Great Red Spot on Jupiter grows and shrinks periodically, but at its greatest area, is 440 square Megameters, which is just below the surface area of Venus.

The surface area of all the planets in our solar system combined is only 125 000 square Megameters. To find an astronomical body with a surface area near the limit of Megaworld, we must leave the

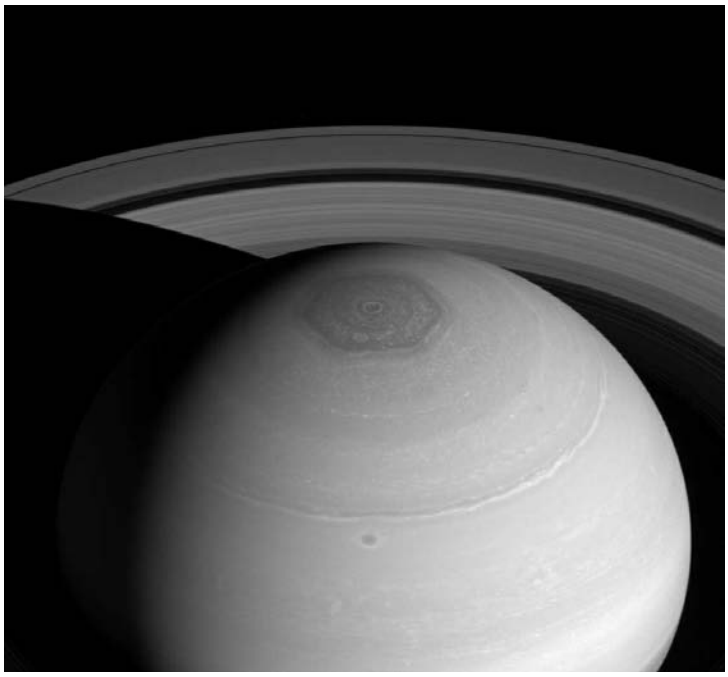

Figure 4.7: Hexagonal cloud formation at Saturn's north pole. "PIA18274-Saturn-NorthPolarHexagon-Cassini-20140402" by NASA/JPL-Caltech/Space Science Institute Licensed under Public domain via Wikimedia Commons

planets behind, and enter the realm of red dwarf stars. Lalande 21185 is a red dwarf in the constellation of Ursa Major (which contains the Big Dipper). It has a diameter of 547 Megameters and a surface area of 938 825 square Megameters.

4.3 Megaworld Volume

1 – 1 000 000 000 Cubic Megameters (Mm^3) 1 x 10^{18} m^3

1 x 10^0 – 1 x 10^9 Mm^3 = 1 Zettaliter (ZL) → 100 000 Yottaliter (YL)

1 – 1000 Megaliters (ML) 1 x 10^6 L

An Olympic sized swimming pool is 55 meters x 25 meters with a recommended two meter depth and holds about 2.5 Megaliters

of water. It would take 1 250 000 two liter bottles of liquid, to fill it.

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The Saturn V rocket, which took Apollo astronauts to the Moon, used 1.6 Megaliters of liquid oxygen to burn about 2.0 Megaliters of fuel to get there.

Figure 4.8: Aftermath of the Boston Molasses Disaster. (Left) The remains of the collapsed storage tank are visible next to the light colored warehouse (Right) Damage to the Boston Elevated Railway

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On January 15, 1919 a large storage tank filled with molasses ruptured. The ground rumbled and failing rivets sounded like the reports from machine gun fire. The storage tank unleashed a torrent of molasses which careened down the city streets of Boston's north end. An 8 meter high wave of molasses washed down the road at 16 meters per second, killing 21 people, and injuring 150 during its rampage. Buildings in the path of the molasses wave were removed from their foundations, and then crumpled under the stress. The amount of molasses released on that day is estimated to have been 8.7 Megaliters.

The enormous steel tank was owned by the United States Industrial Alcohol Company. The tank had a capacity of more than 8000 cubic meters. The molasses was transported by rail to a

distilling plant which converted it to industrial alcohol for munitions. The construction of the tank was finished in 1915. At that time, the tank was supposed to have been tested for soundness by filling it with water. The owners declined to perform this test as a molasses ship was soon to arrive in just a few days. The steel was half the thickness needed for a tank with this large a capacity. The steel also lacked manganese which made it brittle.

When the tank was filled, it began leaking soon after. Rivulets of molasses began to form on the tank's surface. People began to fill containers with the syrup, for use in their households. Groans and rumbles emanated from the tank, but the company management refused to investigate. This new tank held more liquid than any above ground container in the history of the city. The molasses had begun to ferment, which released carbon dioxide. This in turn increased the pressure against the walls inside the nearly filled vessel. The pressure was nearly twice that which would have been deemed safe. The ground shook and a huge rumble was heard as the storage container failed. The resulting wave entangled and engulfed men, women, pets, horses and rats in the sticky fluid. People in cellars were entombed by the viscous blob. Hospital personnel worked to clear the airways of victims. The molasses was so prevalent, it found its way to the wheels of stretchers, which became immovable. Salt water from Boston Harbor was used to clean the affected area. A fireboat sprayed water onto the scene, which emptied back into the harbor, and rendered it brown into the summer. The total mass of the molasses was estimated to be about 13 Gigagrams!

In the lawsuit that followed, the company argued that anarchists had blown up the storage tank with dynamite. The motive was that the molasses had been used to make munitions for World War I. The Plaintiffs Attorney argued that the construction of the tank had been rushed to fulfill war orders. It was asserted the steel company had delivered steel that did not meet specifications. The company had only undertaken a single, partial, leak test where the tank was filled with only 150 mm of water. No architect or engi-

neer was employed to certify the soundness of the structure. The court ruled against the US Industrial Alcohol Company arguing the tank should have been built with a larger safety factor.

In the criminal inquest, the presiding magistrate argued that the government was liable. It was pointed out that no public supervision of the construction had taken place, and that the plans which passed through the building department were approved by persons incompetent to do so. The tax rate was minimized to the point that unqualified personnel were employed to evaluate the construction plans. After the disaster, the Boston building department required all new building plans to have the calculations of the engineers and architects included with the plans. The plans also had to be signed. This practice eventually became standard across the US. Every state required its engineers to be certified. Today a professional engineer must affix their seal to submitted drawings before a state or municipality will issue a building permit.

Megaliter Volumes

Example	Volume
Olympic Size Swimming Pool	2.5 ML
Fuel for Saturn V Rocket	3.6 ML
Boston Molasses Disaster	8.7 ML
Seawise Giant (Supertanker)	320 ML
TI-Class Supertanker	500 ML
Largest Grain Elevator	705 ML
Deep Water Horizon Oil Spill	780 ML
Lakeview Oil Gusher	1400 ML

Table 4.5: Megaliter Volume Examples

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The longest supertanker ever constructed was the *Seawise Giant*, which went into service in 1979. It was 458 meters long, 15 meters longer than the Empire State Building is tall, and too wide to fit through the Suez Canal or the Panama Canal. The latest

class of supertankers, can hold about 500 Megaliters of crude oil.

. . .

The world's largest grain elevator is located in Haysville, Kansas. It is a concrete structure 828 meters long with a storage capacity of 705 Megaliters.

. . .

The Deepwater Horizon oil spill of 2010 lasted 87 days, and released 780 Megaliters of crude oil into the Gulf of Mexico. This amount of oil is approximately equal to the capacity of about two ULCC supertankers.

The Lakeview Gusher Number One (which took place in 1910–1911) was an uncontrolled fountain of crude oil expelled from a pressurized oil well in California. The oil well was thought to contain natural gas, and some small amount of oil, but drilling released an unexpected oil gusher, which overwhelmed the drilling crew and its resources. The oil flow was unrestricted for 18 months and released 1400 Megaliters of oil upon the landscape.

Mm^3 • • • Mm^3

Planetary Cubic Megameter Volumes

Celestial Body	**Volume**
Charon	1 Mm^3
Pluto	7 Mm^3
Mercury	61 Mm^3
Mars	163 Mm^3
Venus	926 Mm^3
Earth	1 090 Mm^3
Neptune	62 540 Mm^3
Uranus	68 330 Mm^3
Jupiter	1 431 300 Mm^3
Saturn & Rings	113 097 000 Mm^3

Table 4.6: Cubic Megameter Volume Examples

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The enclosed volume of a sphere encountered in Megaworld is above the threshold at which most celestial bodies have enough gravity to compress themselves into spheres. A one cubic Megameter sphere has a diameter of about 1.24 Megameters. The mean diameter of Pluto's moon Charon is 1.21 Megameters, and so it is very nearly equal to 1 Mm^3 in volume. A 1000 cubic Megameter sphere has a diameter of 12.4 Megameters, and encompasses a volume on the order of the inner planets of our solar system. Venus has a diameter of 12.1 Megameters and a volume of 926 Mm^3. The Earth's diameter is 12.77 Mm with a volume of 1090 cubic Megameters.

The giant gaseous planets of the outer Solar System require spheres on the order of 1 000 000 cubic Megameters to encompass them. A sphere which encloses 1 000 000 Mm^3 has a diameter of 124 Megameters. Saturn, with a diameter of 120 Megameters, just fits within such a sphere. When Saturn's rings are included, the total diameter is 300 Megameters which contains 113 097 000 cubic Megameters. A sphere with a volume at the upper range of Megaworld, 1 000 000 000 Mm^3 (1 Gm^3), has a diameter of about 1241 Megameters. The upper range of this volume can encompass the entire Earth/ Moon system. The Moon's orbit about the Earth has a mean diameter of 760 Megameters.

4.4 Megaworld Mass

1 – 1000 Megagrams (Mg) 1 x 10^6 g

The expression of mass in Megaworld has been confused by the retention of a pre-metric virtual term called the "metric ton," which is alternatively spelled the *tonne*. The tonne is pronounced the same as ton, which can lead to further confusion. Metric ton is a slang term for 1000 Kilograms, which is one Megagram. The term "ton" is not uniquely defined and has multiple values. For example, the US long ton, which is also the US shipping ton, US dead weight ton, US displacement ton, and US gross ton, is 1016.046 9 Kilograms. The US short ton, which is also the US net

ton, is 907.184 74 Kilograms.

Megagram Mass Items

Example	Mass
Cubic Meter of Water	1 Mg
Great White Shark	1 Mg
Stone in Great Pyramid	2.5 Mg
African Elephant	7 Mg
Paraceratherium	20 Mg
Stone in Stonehenge	45 Mg
Hoba meteorite	60 Mg
Blue Whale	170 Mg
Boeing 777	250 Mg
Common Cloud	500 Mg
Thunder Stone	1250 Mg

Table 4.7: Megagram Examples

The desire to hang onto a pre-metric slang term for a well-defined metric value only leads to confusion, and although the difference between a long ton and a Megagram is only 1.6%, this would clearly be an unacceptable difference to commodity traders.

The use of the non-SI unit metric ton, or t, produces the expression Gt for gigatonne. However a tonne is actually a Megagram, which hides inside of it an implied metric prefix Mega. The expression is a virtual concatenated prefix, which should not be allowed in SI. In other words, the gigatonne Gt is more properly a Giga-Mega-gram, which is actually a Petagram (Pg) when properly expressed in SI. It is strictly forbidden to use concatenated prefixes such as micromicro for pico or KiloMega for Giga in SI. This poor usage obscures magnitude intuition by introducing a proliferation of unnecessary and confusing compound prefixes.

The word ton can be further confused as a unit, because it is also used as power unit and an energy unit. A ton of refrigeration is 3516.852 8 watts, and a ton of explosive energy is 4.814 Gigajoules. We will not use the metric ton (tonne) here; the Megagram will be used exclusively.

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If one constructs a cube with one meter sides, the enclosed volume is one cubic meter. When this cube is filled with water, it has a mass of 1 Megagram and contains 1000 liters.

...

The Great Pyramid consists of approximately 2 300 000 stones which are typically 2.5 Megagrams each.

...

The mass of a male African elephant, the largest living land animal, is approximately 7 Megagrams.

The largest terrestrial mammal known, is the extinct paraceratherium. It was a hornless rhinoceros, which lived around 23-34 million years ago, with a mass of up to 20 Megagrams. Its shoulder height is thought to have been about 4.8 meters with a length of about 7.4 meters.

If ocean-dwelling animals are included, the Blue Whale has a mass of 170 Megagrams, which makes an elephant appear almost dwarf-like by comparison. Indeed a full-grown elephant has about the same mass as a new-born blue whale. The heart of a Blue Whale pumps around 220 liters of blood with every beat.

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An everyday object we see constantly, yet never actually experience directly, is a cloud. What is the mass of a cloud? It turns out the density of a cloud is about 500 micrograms per cubic meter (500 $\mu g/m^3$). This is clearly a very small density, which explains why they float in air, but a common cloud is about equal to a 1 Kilometer cube. This leads to a total mass of 500 Megagrams for a typical cloud. The fluffy white clouds floating in the sky above us, contain far more mass than one would expect. We can also note a gram is approximately a milliliter of water. This allows us to immediately estimate the amount of water in the cloud to be about 500 Kiloliters.

The mass of a Boeing 777 is about 250 Megagrams, or half that of the average cloud through which it flies.

...

The largest stone ever quarried, and moved by humans, is the stone that is the pedestal for Russia's Bronze Horseman statue, known as the Thunder Stone. The 1250 Megagram monolith was moved 6 Km to its present location in St. Petersburg. It was trimmed down from its initial mass of 1500 Megagrams as it was transported. The stone pedestal is larger than the statue it supports. The statue was commissioned by Catherine The Great, to celebrate Peter The Great, who founded St. Petersburg. Catherine was German, and wanted to legitimize her reign by starting a large patriotic project. The stone was moved in the mid 1700s with the best available 18th century technology.

It was initially thought that no stone large enough for the statue would be located. The original plan was to attach six smaller field stones together with metal clamps. On September 7, 1768 a local peasant, and supplier of granite, showed up at the Bureau of Buildings, claiming he thought he had found a big enough rock for the project. The rock was covered with moss, and protruded about 2 meters above the ground, but looked like an excellent candidate. The rock was in a wetland, and about 5 meters of it was below ground. After digging, the workers found it was a boulder, and not attached to any lower rock strata. Its contour was perfect—but how on Earth would they move it?

The effort to move the rock became a patriotic mission. A group of 400 hired hands, and 500 soldiers, were assigned to transport the monolith. They excavated about 5 meters below the surface with a 30 meter radius around the rock. The Thunder Stone was 12.8 meters long, 8.23 meters wide, and 6.4 meters high. Before transport, the rock was first lain on its side, a Herculean task in itself. Trees were cut down, halved and hollowed to produce a half-pipe with rounded bottoms into which copper was formed. Next copper balls were used as a set of ball bearings to convey the rock along a pair of wooden tracks spaced five meters apart. The plan looked good, but the rails sunk 450 mm into the mud rendering them useless. The crew had to wait until the Russian

winter would render the ground solid, and try again.

The workers used the intervening time to layout rails, and strengthen the path with stones, in preparation for the coming winter. The ground froze to a depth of 1200 mm, and the crew initially moved the Thunder Stone about 50 meters. The rock moved with ease using capstans to usher it along, and control its speed on downgrades. The crew was able to move the Thunder Stone around 150 to 400 meters per day. The tracks were taken from the rear to the front and reused as it was transported.

The success became widely known, and spectators arrived to watch the procession of the monolith. The Thunder Stone was moved to the Gulf of Finland, where they needed to determine a method to transport it by water. The engineers built a barge that was 58 meters long and 21 meters wide. Two sailing ships were deployed on either side of the barge to provide locomotion through the gulf to the outlet of the Neva river. The rock was conveyed up the Neva river past Catherine The Great's Winter Palace to its present location, where it remains to this day.

The transport of the Thunder Stone was an engineering achievement celebrated around the world at the time. Fragments of the rock, which were so much detritus along the transportation path, became valuable. They were collected and polished for use in jewelry and as knobs for walking sticks. The statue was revealed on August 7th, 1782.

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