The Moons of Nibirum

Drawing on information compiled when designing Nibirum's Solar System, visible-disc images for Nibirum's two natural satellites as seen from the planet, the White and Red Moons, were constructed using CC3+. This process also used details regarding the appearance of Earth's Moon, reworked using the random-generation mechanics available in CC3+, as described in this ProFantasy Forum topic:

`http://forum.profantasy.com/comments.php?DiscussionID=8242`

While not strongly detailed, and with features deliberately blurred, this process resulted in reasonable representations for how the Moons should look in Nibirum's night sky, remembering that the White Moon, with an apparent diameter of 0.62°, seems only slightly larger than Earth's Moon (0.5° across), while the Red Moon has a visible disc just 0.1° in size. An apparent-size scale diagram including Nibirum's and Earth's Suns and Moons is included as *Appendix A* on page 7 of this document.

The Nibirum Eclipse Calculator Chart

This can be used to help visualise where the White and Red Moons are relatively in their orbit about Nibirum compared to the Sun, and so tell what phase the White Moon will currently show, along with the likelihood of a solar or lunar eclipse happening, or a transit of the solar disc by the Red Moon (whose apparent disc is too tiny to cause eclipses for Nibirum). It is also useful for telling something about the ocean tides on Nibirum itself.

The Calculator Chart should be printed-off for best use. For added durability, it could be fixed to good-quality stiff cardboard and protected further with a covering of clear, self-adhesive, film, while the Markers, once similarly card-backed, can be cut out and placed on their respective tracks to show what feature is where and when. A ruler or other straight-edge can be helpful in working out any important alignments more precisely.

A north-pole view of Nibirum is shown in the centre of the Chart. A convenient small white cloud in its middle has been so-placed to show the north rotational pole of the planet. The concentric tracks surrounding Nibirum are all central to that point, and are also viewed as if looking down onto them from their northern sides. Note that the images and tracks are representational only, and are not to-scale.

Each track contains a variable quantity of numbered spaces of different sizes. Each is also shaded and labelled as a reminder of what orbital feature around Nibirum it represents, with arrows showing which way the features on it move, labelled to indicate at what speed on the lower left side. The Markers are comparably colour-coded, while the track numbers allow the random placement of specific markers when initially setting-up the Chart for RPG use (or the first such marker per track, as the other depends on where that first lies on the track).

Outwards from the centre, these tracks are:

* **Perigee-Apogee:** Orange colour, 12 x 30° spaces, motion is counter-clockwise at a speed of one space per Nibirran year. Two markers, labelled "P" = Perigee and "A" = Apogee.

* **Nodes:** Blue colour, 24 x 15° spaces, motion is clockwise at a speed of one space per year. Two markers, labelled with the conventional Earth-astronomy signs for the Ascending (☊) and Descending (☋) Nodes. On Earth, these Nodes are also called respectively the Dragon's Head and Dragon's Tail.

* **Moons:** Cream colour, 24 x 15° spaces, motion is counter-clockwise at a speed of one space per Nibirran day. Two markers, one showing the White Moon, the other the Red.

* **Sun:** Red colour, 36 x 10° spaces, motion is counter-clockwise at a speed of one space every ten days. One marker, showing the Sun.

Outside the Sun track are degree labels that correspond to the labelling of the Nibirum Sky Maps. Projecting a straight line from the centre of the Nibirum planet symbol outwards through the location of any marker on its track will show the approximate sky-position on or near the ecliptic for that marked feature at the given time as seen from Nibirum. The 0° direction is that of Nibirum's northern spring equinox when the Sun is there, 90° is the northern summer solstice, 180° the autumn equinox point, and 270° the winter solstice similarly.

Some further details regarding each track, what it represents, the events associated with it, and how to make best use of it, follow.

Perigee-Apogee Track

This feature can be ignored by those not wishing such extra detailing with no especial problems. However, it does reflect the fact that Nibirum's lunar orbit, like that of Earth's Moon, can be considered off-centred from the centre of the main planet. This creates two facets of notable interest for RPG use concerning Nibirum's White Moon - variable tidal ranges on Nibirum, and the possibility of annular solar eclipses.

At perigee, the White Moon is nearest Nibirum, at apogee furthest away. So at perigee, it appears slightly larger than normal - about 0.63° across (the average is around 0.62°) - at apogee, a little smaller, 0.61°. Thus a New Moon at apogee which could otherwise cause a total solar eclipse (see the Nodes Track description on pages 3-4 below on this), will instead cause only an annular eclipse, where a thin ring of the 0.62° diameter solar disc remains visible around the Moon's darkened disc at mid-eclipse.

Again like Earth, Nibirum's tides are governed primarily by the relative positions of its White Moon and Sun compared to the planet. When both lie on the same, or on directly opposite, sides of Nibirum, so at New or Full Moon, the highest and lowest tides occur, that is the tidal range is at its greatest, called "spring tides" on Earth (unrelated to the season). When the two are at right-angles to Nibirum (around First or Last Quarter Moon), "neap tides" happen, with the lowest overall tidal range, much closer to the average.

However, the tidal range is always increased when the Moon is near perigee, and decreased when near apogee. This can cause coastal flooding, and flooding of low-lying areas by tidal rivers, during perigee-influenced spring high tides, particularly when there has been increased water runoff from the land shortly before this happens (such as snowmelt, or recent heavy rains). The unusually low tides also caused at such times can conversely reveal otherwise submerged offshore features too.

The Perigee and Apogee Markers are always directly opposite one another on the Chart's track, six spaces apart - so if the Perigee Marker is in space 2, the Apogee one must be in space 8, for instance. Each moves one space anticlockwise around the track per Nibirran year. The influence of either extends into the neighbouring spaces on the Nodes and Moons tracks. The motion of these points, taking 12 years to cycle through once for Nibirum, is slower than for Earth, where the cycle takes only 8.83 years.

Nodes Track

This is important in restricting the frequency of eclipses. It concerns the fact that the Nibirum lunar orbit is inclined at 4° to the ecliptic (the apparent path of the Sun through the sky as seen from Nibirum, though it is actually that planet's orbit projected onto the sky). The orbit of Earth's Moon has a similar inclination of about 5°. That inclination means the lunar orbit and the ecliptic coincide at just two points, the **nodes**, one where the Moons pass south to north of the ecliptic, the Ascending Node or Dragon's Head, the other north to south at the Descending Node or Dragon's Tail.

The two Node Markers must be always directly opposite each other on their track, that is, 12 spaces apart. If the Descending Node Marker is in space 4, the Dragon's Head one must be in space 16, and so on. Unlike all the other markers, those for the nodes move the "wrong way" - though actually clockwise as viewed on the Chart - at a speed of one space each Nibirran year. A nodal regression of 15° per year equates to either node completing one full circuit of Nibirum every 24 years, a pace somewhat slower than the equivalent regression for the nodes of Earth's Moon (roughly 19.25° per year, thus taking about 18.7 years per cycle, Earth time).

It is at or near these crossing points that either of Nibirum's moons can pass in front of the Sun as seen from Nibirum, or where Nibirum can stop the Sun's light from reaching the moons directly, resulting in an eclipse, or for the Red Moon (which is too small to conceal much of the solar disc) a transit. Each of these is discussed in detail by the following sections.

Solar Eclipses: As the White Moon and Sun have small but distinct discs as seen from Nibirum, just like the view from Earth of its Moon and Sun, when New, the White Moon can pass in front of at least a tiny portion of the solar disc when up to 11° or so to either side of either node. However, at least half the solar disc would need to be covered by the Moon for more than a few experts using magical or optical aid to view, or indeed even notice, the event. Such a deeper eclipse could only occur when the alignment of the Sun and Moon was within roughly 7° of the node.

Thus a major, obvious-to-most, solar eclipse can only happen for Nibirum when the Markers for the White Moon, Sun and either Node are in immediately adjacent spaces on their respective tracks. For example, Sun Marker in space 26 or 27, White Moon Marker in space 18, and either Node Marker in space 8. This can be further restricted if desired, since only the second half of solar space 26 coincides with the other two marker spaces in this example, so providing an extra time-dependence, especially when coupled with the relatively rapid motion on its track of the White Moon.

The approximate direction of the Moon's path over the Sun can be told by which Node is involved, while the length of the eclipse can be estimated by the proximity of the Perigee or Apogee Marker to the others. The Perigee Marker in its space 9 for the above example would mean the deepest solar eclipse possible, lasting about 2.1 Nibirese hours for any given site on the total eclipse's surface path, in the midst of which would be the total phase (solar disc entirely concealed), lasting a little over 0.016 hours (about one minute of Earth time). The eclipse overall, and its total phase would be shorter for other configurations, down to momentary total-phase events where the Apogee Marker was in space 8 or 10, while if that Marker were in space 9, there would be no total phase at all, simply an annular eclipse, where a ring of the bright Sun would remain visible around the dark disc of the White Moon at mid-eclipse (as the lunar disc at apogee is 0.61° across, while the Sun retains its normal 0.62° diameter).

A further layer of complexity can be added by allowing experts to instrumentally observe minor partial solar eclipses when the Sun and White Moon Markers are adjacent to one another as usual, but up to half a Node-track's space to either side of the Node Marker. So for the above example with the Node in space 8, the Sun Marker could be in space 28 and the White Moon one in space 19, or in spaces 25 and 17 respectively, and a minor partial eclipse might still be seen by those most knowledgeable.

As for where on Nibirum, and when, a solar eclipse could be observed, even using this simplified system, there are too many variables to provide a straightforward guide. Careful measuring on the Eclipse Calculator Chart can give some general timing information at least, while the projection of the 0.62° eclipsed solar-lunar disc's shadow onto Nibirum gives a minimum physical width for the total eclipse path of around 70 km roughly north-south on the surface (for a point where the surface is at right-angles to the Sun-Moon line). Within that zone, the Sun would be fully concealed, for longest close to the path's centre, with the total-phase's duration decreasing towards the path's northern and southern limits. From Earthly solar eclipses, the length of the path from which totality may be seen while the Sun and Moon remain in alignment often runs across more than 90° to 120° of longitude approximately west to east, which converts to a distance between *circa* 10,000 to 13,500 km on the surface of Nibirum.

The region from where a partial eclipse can be seen, down to the very tiniest phases, completely surrounds the narrow total-phase path, and can encompass almost half the hemisphere facing the Sun during the eclipse at different times. For eclipses with no total or annular phase, this visible region for the event reduces to maybe one-quarter of the planet's facing hemisphere or less.

In a fantasy RPG campaign, unless the GM is comfortable with the computations involved, probably it would be better to select a suitable track from an Earthly eclipse, and simply apply that to the desired area of Nibirum instead. The parameters for both at a global level are sufficiently similar that this should not need more than a few small amendments, something especially true given such an event will most likely be used only as a plot-device for a small region of the planet in the current storyline.

Lunar Eclipses: While the frequency of solar eclipses for Nibirum is not dissimilar to what we find from Earth (relatively rare), because Nibirum's White Moon is smaller and closer to Nibirum than Earth's Moon to Earth, Nibirum experiences significantly more lunar eclipses than Earth does. In a lunar eclipse, Nibirum passes between the White Moon and the Sun when the Moon is Full, so casting its shadow across the lunar disc, darkening and often reddening the Moon, sometimes to the point of near-invisibility.

A lunar eclipse can only happen when the Sun Marker is directly opposite the White Moon Marker on the Eclipse Calculator Chart, with the centre of the Nibirum symbol lying exactly in between (use the central white cloud over Nibirum's north pole as a defining point if needs-be). For the example this time, if the Sun Marker is in space 14 of its track, the White Moon Marker must be in space 21 of its track to be Full. (Note that this example deliberately includes a note of ambiguity, because the latter part of solar space 14 is also directly opposite the first part of lunar track's space 22 as well. For those wishing greater precision, the specific dates can be used along with the general guidance the Chart provides.)

One of the Node Markers must be near the Moon Marker as well. However, the relatively large shadow cast by Nibirum at the White Moon's distance means at least a tiny part of the lunar disc can be within that shadow even if the node is up to 30° or so away. Around half the lunar disc will be shadowed if the node is no more than 25° distant, while the eclipse will be total once the nodal separation is 22° or less, albeit only momentarily at that extreme limit. The closer the node is to this alignment, the longer the duration of the eclipse and its total phase will be, up to a maximum of roughly 8.4 Nibirran hours, of which totality will persist for the central *circa* 6.25 hours.

Consequently, an "expert-observable" partial lunar eclipse, where only a small part of the lunar disc is fully shadowed, could occur in our example set-up - Sun in 14, Moon in 21 - if the nearest Node Marker was in node track spaces 3 or 7. At least a half-phase eclipse would happen with the Node Marker in spaces 4 or 6, while a total eclipse would need the Node Marker to be in space 5. If preferring greater precision though, the eclipse would be total if the Node was in space 5 or the immediately adjoining halves of spaces 4 or 6.

The location of the Perigee or Apogee Markers to the markers involved in a lunar eclipse make little difference to the appearance of the event overall at anything beyond an extremely precise level. A perigee eclipse would be marginally shorter (Moon's disc slightly larger and its motion fractionally swifter), an apogee one slightly longer, is all.

A lunar eclipse would be visible from anywhere on Nibirum where at the time it took place it was night, and the White Moon was above the horizon.

In terms of the eclipsed Moon's appearance, Earth's own lunar eclipses form a useful guide to the shape of the shadow on the lunar disc, and the colours involved (along with the latter's variability), at least for eclipses where the Nibirran total phase lasts no more than 2 to 2½ hours (the longest Earthly total lunar eclipses last about two hours in that state). While this covers many Nibirran lunar eclipses, some can last significantly longer, in which the White Moon can become so dark, it can be seen no longer with the unaided eye, something that can persist for the central part of such an event - so for perhaps the middle 1.25 to 2.25 hours out of a 6.25-hour total eclipse.

The frequency of these lunar eclipses (occurring at about half the Full White Moons every Nibirran year) reduces their impact as spectacles for the planet's population, so only those rarer ones where the eclipsed Moon is unusually coloured, bright, or particularly dark, say, may be much remarked upon, or treated as notably ominous. More generally though, all such eclipses could remain important for some magical or mystical practices.

Red Moon Events: As noted in the description of the Nibirum Solar System previously, the Red Moon shows no phases, and aside from a period of roughly 6 to 8 days of invisibility when nearest the Sun in Nibirum's sky, it is usually seen as a tiny, dull red disc in the night sky, about magnitude +3 compared with the stars, and trailing the White Moon by some 60°. This is so even when the Eclipse Calculator Chart suggests it could be

eclipsed were it the White Moon near its Full position. Partly this is because the Dog Moon always receives some light, either directly from the Sun, or as reflected from the ♀ Moon and/or the illuminated part of Nibirum (or as refracted through Nibirum's atmosphere). Partly - well, this is up to GMs to decide, but perhaps something mysteriously magical operates too!

At less than one-sixth the apparent size of the solar disc, the Red Moon can never produce solar eclipses for Nibirum. However, at times when the Chart suggests a solar eclipse alignment for it - with the Sun, Red Moon and a Node Marker all in immediately adjacent track spaces, so at its New position, such as with the Sun Marker in space 4, Red Moon Marker in space 3 and one or other Node Marker in space 23 - a **transit** of the Red Moon across the Sun can be seen from Nibirum. This can be observed only by those experts using safe solar viewing techniques, something usually needing an optical or magical device. The Red Moon then appears as a 0.1° diameter black disc that slowly moves over the brilliant 0.62° diameter solar disc, an event lasting at most about 1.25 Nibirran hours (for a midline transit across the centre of the Sun's disc). The significance placed upon such an occurrence, rarely known beyond a few sages and specialists, is best left for GMs to decide. Perigee and Apogee have no significant effect on the appearance of the Red Moon, while transits can happen only when the alignment lies within approximately 5.5° of the Node, for those seeking greater precision.

Moons Track

Both White and Red Moon Markers use this track, the White always 4 of the track's 15° spaces ahead of the Red Moon. So if the White Moon is in space 2, the Red must be in space 22, for instance. There are 24 such daily-motion spaces on this track, which track describes one complete orbit of Nibirum for each Moon. However, as the White Moon shows distinct phases, which are dependent upon the Moon's angle to the Sun as viewed from Nibirum, the time needed for any given phase to repeat itself from the planet is 26 days, because the Sun also seems to be in constant motion, thanks to Nibirum being in orbit around it. Thus although the Moons orbit Nibirum 15 times for every 360-day orbit Nibirum makes around its Sun, there are only 13 or 14 (an average of 13.85) of any given White Moon phase in that same period. An equivalent set of 15 complete lunar-phase cycles takes 390 Nibirran days to complete. These two cycles come back into step - same White Moon phase on the same day of the year - after 13 Nibirran 360-day orbits, or 12 390-day "lunar-phase" orbits.

Thus the Moons Track does not show a whole, say, New Moon to New Moon cycle for the White Moon, only 24 days of that. The White Moon's timing within its phase-cycle is: ● = New = Day 1; ◐ = First Quarter (or Waxing Half) = Day 6.5; ○ = Full = Day 13; ◑ = Last Quarter (or Waning Half) = Day 19.5; ● = New again = Day 26. If the first New Moon was in space 1, the next would be in space 3, and so on.

Sun Track

Divided into 36 x 10-day spaces, this covers an entire Nibirum orbit around its Sun, albeit perceived from the planet as the Sun orbiting it, of course.

Appendix A: The Apparent Sizes of Nibirum's Sun and Moons

To help better visualise the apparent sizes of the Sun and Moons as seen from Nibirum, the following is a scale diagram which, if printed out at actual size with no printer scaling applied, and then held at arm's length from the eye for most people, will give a useful approximation of what would be seen. As a further guide, for angles up to *circa* 25° or so, 1 centimetre at arm's length from the eye is roughly 1° in angular size. These images were scaled using 1.16 cm = 1°, which is a still-closer approximation. Shaded circles showing the apparent angular sizes of Earth's Sun and Full Moon are also provided for comparison, along with a 1 cm square scale box (its internal cross-lines are set at 0.5 cm). Two contrasting background colour options are provided as well.