Ellendria - The Making of a Planet

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Designing a solar system for Hauldryn (officially HIP 18433) was one of the first world building tasks that I set for myself. Hauldryn is the home sun for a number of the major characters in my novel, and having a good working knowledge of this system will assist in many of my descriptive scenes.

To start with, I know a few basic elements from my “general understanding” of the universe that I’m creating:

1. Planets inhabited by humans are going to have environments fairly close to Earth normal. They have been specifically selected for colonization, and why would an intelligent race try to colonize a planet that was excessively hot or cold or had extreme gravity?
2. Planets inhabited by humans have been bioengineered to support human biochemistry. Consider that we have enzymes that allow us to consume only certain types of organic molecules. I really don’t believe you could land on a totally alien planet, pick a piece of fruit off the nearest tree, consume it, and successfully obtain nutrition from it, assuming it doesn’t poison you first. This will result in flora and fauna that closely resembles what we see on Earth today, give or take a bit of evolutionary drift.
3. For the specific purposes of my story-telling, I want Ellendria to have a slightly higher than Earth normal gravity, slightly lower levels of oxygen, and a day length and year length that is similar to Earth’s.

So now we get to some science. People have been asking the question “What makes a habitable planet?" for years. Scientists in various disciplines have come up with the following hypotheses:

1. Conditions need to be such that liquid water can exist on the surface of the planet for life as we know it (e.g., humans).
2. The spectral class of the host star needs to be in the range of a "late F" to a "G" to a "mid-K". This allows for several important factors:
    - Stars of these classes live at least a few billion years, allowing life a chance to evolve, or conversely, providing a colony with a potentially long existence.
    - These stars emit enough high-frequency ultraviolet radiation to trigger important atmospheric dynamics such as ozone formation, but not so much that ionization endangers life.
    - They emit sufficient radiation at wavelengths conducive to photosynthesis (an absolute necessity for the bioengineering process to be successful).
    - Liquid water may exist on the surface of planets orbiting them at a distance that does not induce tidal locking. A tidally locked planet has one side that always faces the sun. This side would likely become extremely hot, whereas the other side would become too cold. There have been some hypotheses on how life could survive on tidally locked planets, but again, for the purpose of my story, why would anyone want to colonize an extreme planet? I might add here that my universe has FTL (faster-than-light) capabilities, and its peoples not being limited by their abilities to reach potentially habitable worlds.
    - At this stage, I'm going to apply another story-telling criteria – the Ellendoria, the original race that colonizes the region of space known as the Ll'Ellendryn, has chosen only to colonize planets orbiting Class G stars, stars which are most like Earth's sun.
3. The planet must be located in a stable circumstellar habitable zone (HZ). At the inner edge of the HZ, water only exists in gaseous form, while at the outer edge, water is only present as a solid. In between these two extremes, liquid water can be found on the planetary surface. For this zone to be stable:
    - The host star must not be increasing in luminosity too quickly. All stars become brighter as they age, thus forcing the HZ to migrate outwards. For the purposes of my tales, this outward migration of the HZ is already beginning for Hauldryn, Ellendria's host star.
    - No large-mass body, such as a gas giant, should be present in or relatively close to the HZ, thus disrupting the formation of Earth-size bodies.
4. The host star must not have large fluctuations in stellar luminosity, which could expose organisms to lethal doses of gamma ray and X-ray radiation.
5. The host star must have high metallicity. Planets forming around a metal-poor star would probably be low in mass, and thus unfavorable for life. Additionally, planets with low metal contents themselves would provide little support for advanced technology. Due to the fact that younger stars have higher metallicity than older ones, habitable systems are more likely to be found around stars of younger generations.

6. Human-habitable planets must be terrestrial, composed largely of silicate rock.
7. To be habitable, a planet needs sufficient mass. Too little mass, and the planet will have insufficient gravity to retain an atmosphere (e.g., Mars). Smaller planets have smaller diameters and thus higher surface-to-volume ratios than larger ones. As a result, they tend to lose the energy left over from their formation quickly and end up geologically dead, lacking volcanoes, earthquakes and tectonic activity. Plate tectonics appears to be crucial, as the process recycles important chemicals and minerals, fosters biodiversity through continent creation and increased environmental complexity, and helps create the convective cells necessary to generate a magnetic field. A magnetic field is necessary to protect the planet from cosmic rays and solar flares which could prove to be lethal to life.
8. On the other hand, the planet cannot have too much mass. Although research has shown that it is theoretically possible for a human to adapt to a gravity that is between 2x and 3x that of the Earth, I think a more realistic range of gravity tolerance would be between 0.8x and 1.2x Earth normal.
9. The planet must have a massive planet well outside its orbit, like Jupiter, to divert potential devastating asteroids away, or to make them destroy themselves (as in the asteroid belt).
10. The eccentricity of the planet's orbit must not be too high. The greater the eccentricity, the greater the temperature fluctuation on a planet's surface.
11. The planet should have a moderate axial tilt, thus generating planetary seasons. Too little tilt and the seasons will not occur. Seasonality is a main stimulant to biospheric dynamism. The planet would also be colder, as warm weather near the equator would not be able to move poleward, and a planet's climate would become dominated by colder polar weather systems. Too much tilt and the seasons would be extreme and make it more difficult for a biosphere to achieve homeostasis.
12. The planet should rotate relatively quickly so that the day-night cycle is not overlong. If a day takes years, the temperature differential between the day and night side will be pronounced. Also, a relatively rapid rotation is necessary to generate a planetary magnetic field. From a story-telling perspective, I want the planet to have a day length that is not too dissimilar from Earth's so that there are similar cultural adaptations.
13. The planet must have a sufficiently massive moon, or moons, in order to stabilize the planet's axial tilt and help moderate the climate. Moons also contribute significantly to ocean tides, thus preventing the stagnation of the ocean and playing an important role in the planet's dynamic climate.

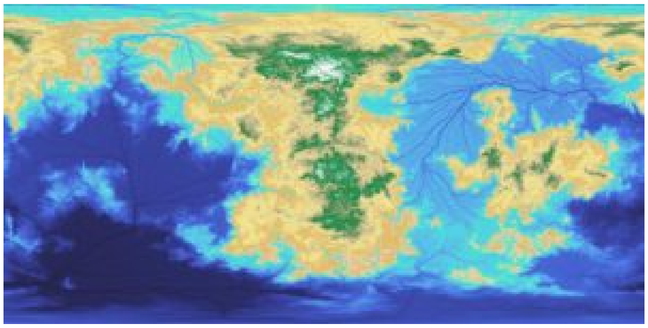
OK, so that's a lot of stuff to think about. However, much of this information can be distilled into mathematical equations and simple computer routines. This is where a bit of pseudo-random world generation comes in. Probably the best know program for doing solar system designing is little piece of freeware known as StarGen. It can be run online, or downloaded and run offline. There are settings to limit the types of systems that are generated, and it is also possible to specify the star to be used. Once the program was set up, I just kept running it until I got a system that matched all my imaginative criteria. Ultimately, this process generated all the necessary physical parameters that I needed to design a complete solar system for Hauldryn – 10 planets and their associated moons.

So what does Ellendria look like? In my mind's eye, I was looking for a planet that was roughly 40% land, 60% ocean, with a terrain that was largely desert. So another tool was required. This one is called Wilbur. Using Wilbur, I was able to generate a height map – this took a few tries until I got one that was aesthetically pleasing to me.

Doesn't look much like a world map yet, does it? Wilbur is designed to simulate erosion processes, and thus create more realistic looking landforms. So, I added some erosion.

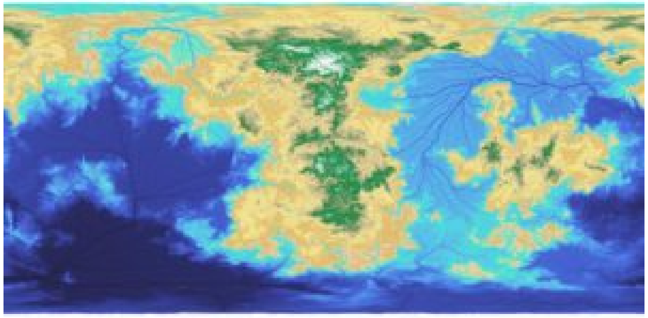
Looking a bit better now? You can see the larger river systems that have been created by the erosion cycle.

Adding some color helped differentiate land from ocean. Getting the colors to look real was tough. In the end, I looked at a bunch of true color satellite image for Algeria, the Nile Delta, the Tarim River Basin in Taklamakan Desert, China, the Gobi Desert, and some shallow ocean reef systems. Using these, and Photoshop, I was able to pick out my color palette, and then set up to color gradients for my landscape.

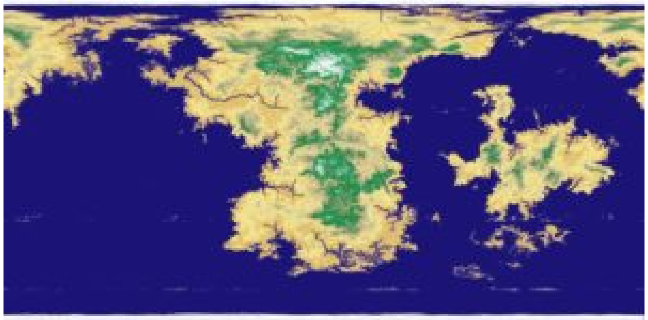


This image reminds me a bit of Marie Tharp’s 1977 world ocean floor map, a copy of which I have had over my desk or in my lab since 1988 (I still have the map, carefully rolled up, in our little 20’ x 20’ cabin, but there is not enough wall space to display it).

Ellendria still has a little bit of ice at her poles, although much less than Earth. I was unable to find a simple way to generate an ice layer for my image, so I simply hand brushed the ice caps in using Photoshop.



Now, when you are observing a planet from space, you don’t generally see the sea floor bathymetry. I went back to Wilbur to generate a sea mask, which was used to apply a simple, unvarying blue color to the oceans.



Personally, I kind of prefer the version that shows the bathymetry. I guess I like my reality painted over with a bit of imagination …

The next step in this process was to make a flat map into a spherical world. This was done using Celestia. However, to make this happen, I needed a couple more things – a normal map (a type of texture map that allows the addition of surface details such as bumps, grooves, and scratches; this was generated using Wilbur), a specular map (a map which shows where the direct reflections of light sources occur in the model, which typically show up as bright highlights and shine; this was generated using yet another piece of open source software, called Awesome Bump), and a cloud layer (generated by a program called Textures for Planets). I'd like to say that you can just dump all your images into Celestia and a nice 3D globe pops out, but it isn't quite so easy. A little hand coding is required. But here it is ….

This version shows the ocean bathymetry …

… and this one is the more realistic view. I’ve taken a bit of artistic license with the atmosphere – it is a much thicker and more visible layer than would be observable from outer space, but I wanted to emphasize this very important element of a living planet.