

# **3D Earth and Celestial Bodies**

*MATLAB Implementation*

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# 1 Download and Installation

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## 1.1 Download from MATLAB Central's File Exchange

The `planet3D` function is available for download on MATLAB® Central's File Exchange at <https://www.mathworks.com/matlabcentral/fileexchange/86483-3d-earth-and-celestial-bodies-planet3d>.

## 1.2 Download from GitHub

The `planet3D` function is available for download on GitHub® at <https://github.com/tamaskis/planet3D-MATLAB>.

## 1.3 Files Included With Download

There are five files and one folder (storing the images) included in the downloaded `zip` file:

1. `3D Earth and Celestial Bodies - MATLAB Implementation.pdf` – *this PDF*
2. `background.m` – *MATLAB function for setting the plot background*
3. `EXAMPLES.M` – *examples for using the planet3D and background functions*
4. `Images` – *Folder that stores images needed to render celestial bodies. DO NOT DELETE. KEEP IN THE SAME FOLDER AS planet3D.m*
5. `LICENSE` – *license for the planet3D function*
6. `planet3D.m` – *MATLAB function for drawing Earth and the major celestial bodies in the solar system*
7. `README.md` – *markdown file for GitHub documentation*

## 1.4 Accessing the `planet3D` Function in a MATLAB Script

There are **three** options for accessing the `planet3D` function in a MATLAB script:

1. Copy the `planet3D` function to the *end* of your MATLAB script.
2. Place the `planet3D.m` file in the same folder as the MATLAB script.
3. Place the `planet3D.m` file into whatever folder you want, and then use the `addpath(folderName)` command<sup>1</sup> where the `folderName` parameter is a string that stores the filepath of the folder that `planet3D.m` is in *relative to* the folder that your script is in.

In all three cases, the `Images` folder **must** be in the same folder as `planet3D.m`.

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<sup>1</sup> <https://www.mathworks.com/help/matlab/ref/addpath.html>

## 2 planet3D

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Creates high-resolution renderings of the Earth and the major celestial bodies in our solar system for space mechanics applications.

### Syntax

---

```
planet3D(planet)
planet3D(planet,position)
planet3D(planet,position,units)
```

**NOTE:** If you don't want to specify `position`, for example, but *do* want to specify `units`, then you would use the syntax `planet3D(planet, [], units)`. The empty brackets are needed as placeholders, because `units` can only be read correctly if it is the *third* passed parameter. However, we don't need placeholders if we aren't "skipping over" parameters. For example, if we wanted to specify just the `position`, we could use the syntax `planet3D(planet, position)`.

**NOTE:** Use the `background` function (see Section 3) to set the plot background. When using `background` to set the plot background, the function call on `background` must occur *before* the function call on `planet3D`, otherwise the background will be plotted *over* the celestial body.

### Description

---

`planet3D(planet,position,units)` draws a celestial body.

<code>planet</code>	'Sun', 'Moon', 'Mercury', 'Venus', 'Earth', 'Earth Cloudy', 'Earth Night', 'Earth Night Cloudy', 'Mars', 'Jupiter', 'Saturn', 'Uranus', 'Neptune', or 'Pluto'.
---------------------	--

<code>position (optional)</code>	Specifies the position of the celestial body. If <code>position</code> is not specified, the function defaults to (0, 0, 0). NOTE: If you are also specifying <code>units</code> , make sure you input <code>position</code> in the correct units (i.e. in the units you intend to use).
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<code>units (optional)</code>	Specifies the units the celestial body should be drawn in. Units available are 'km', 'AU', 'm', 'ft', 'mi', and 'nmi'.
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## 3 background

---

Sets the plot background for drawing celestial bodies in 3D.

### Syntax

---

```
background(spec)
```

**NOTE:** The function call on `background` must occur before the function call on `planet3D`.

### Description

---

`background(spec)` sets the plot background for drawing celestial bodies in 3D. `spec` refers to the specified background, and can be set to '`Black`', '`Stars`', or '`Milky Way`'.

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## 4 Example Plots

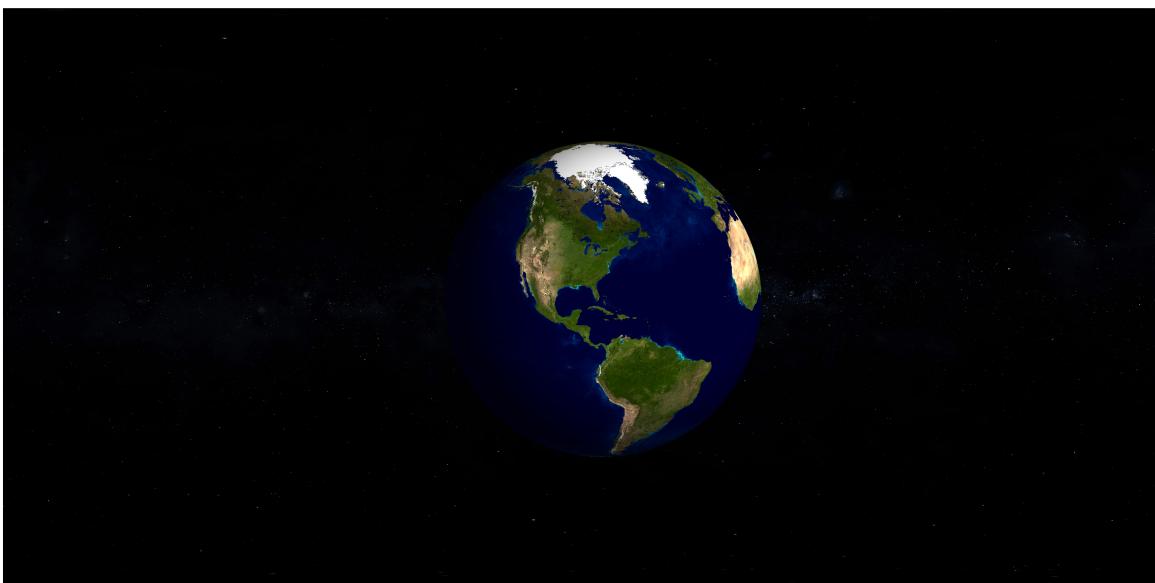
---

### 4.1 Earth

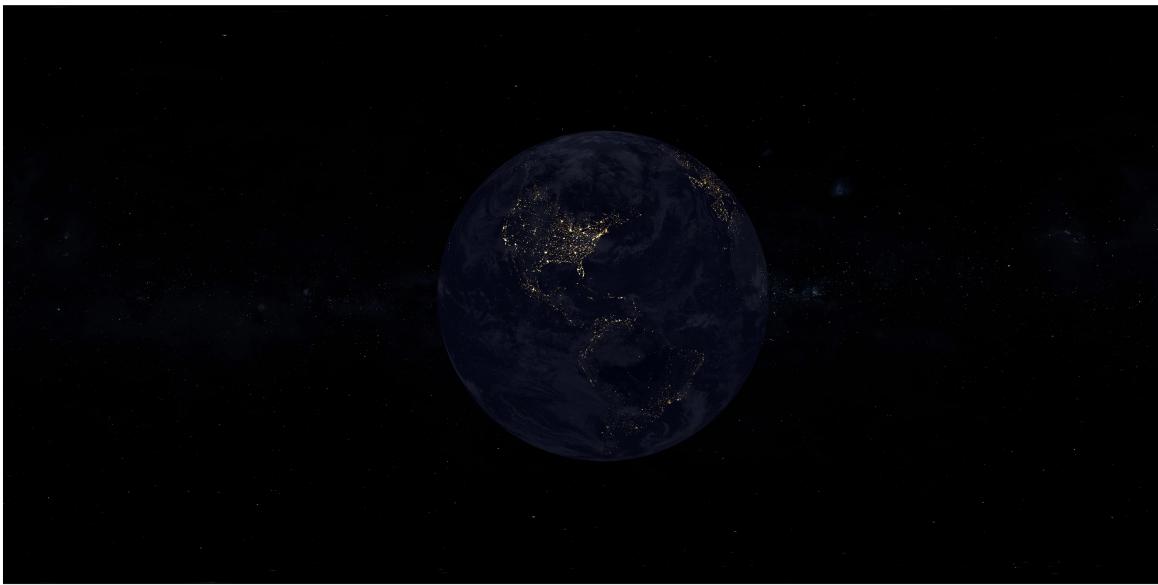
#### 4.1.1 | Earth (With Clouds)



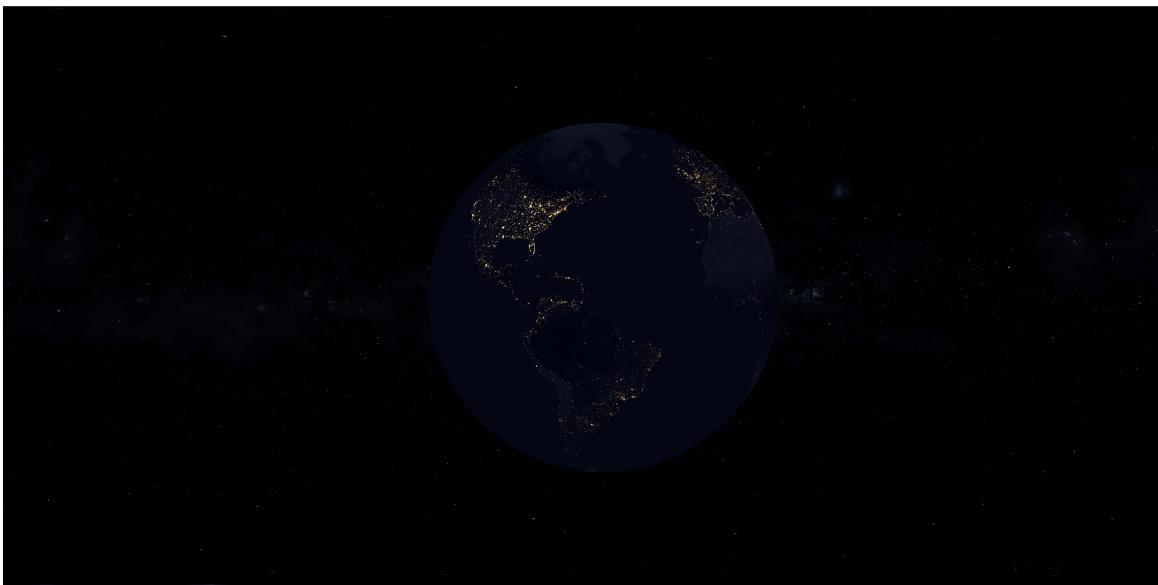
#### 4.1.2 | Earth (No Clouds)

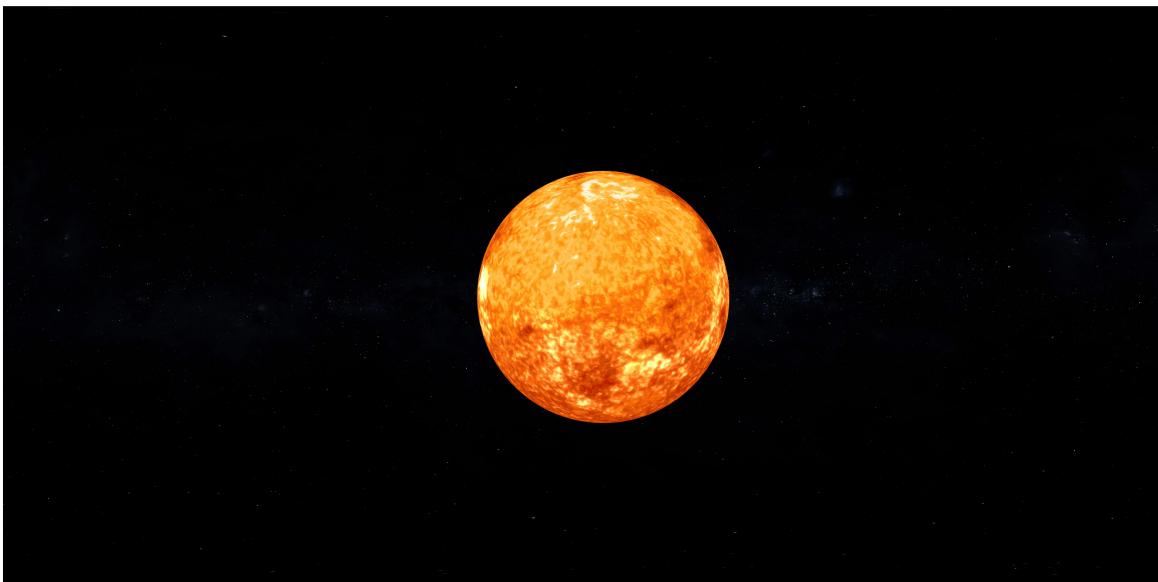


#### 4.1.3 | Earth (Night, With Clouds)



#### 4.1.4 | Earth (Night, No Clouds)

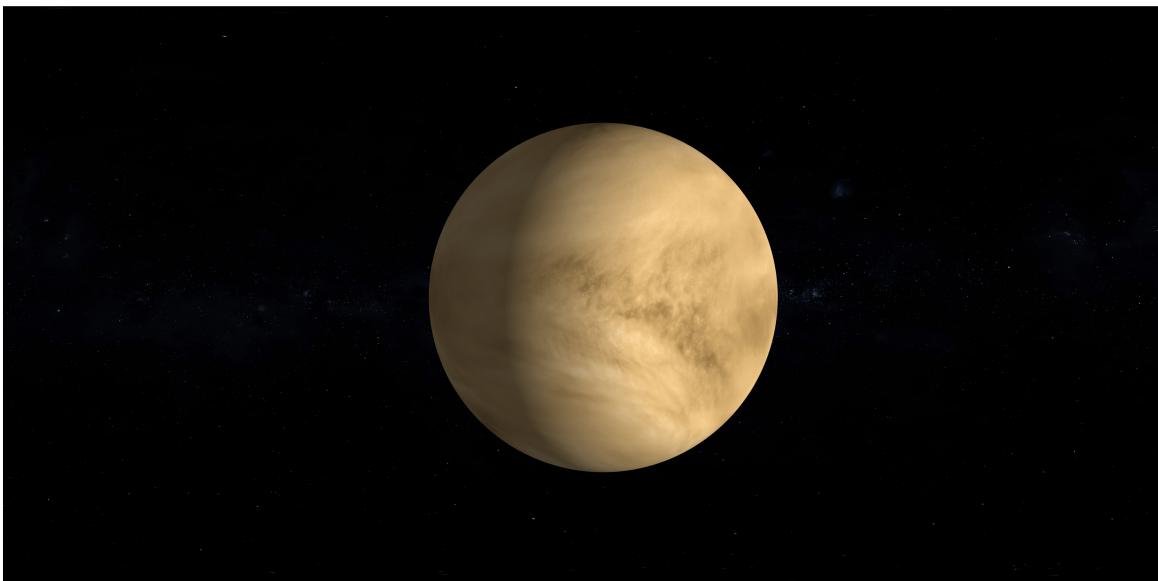


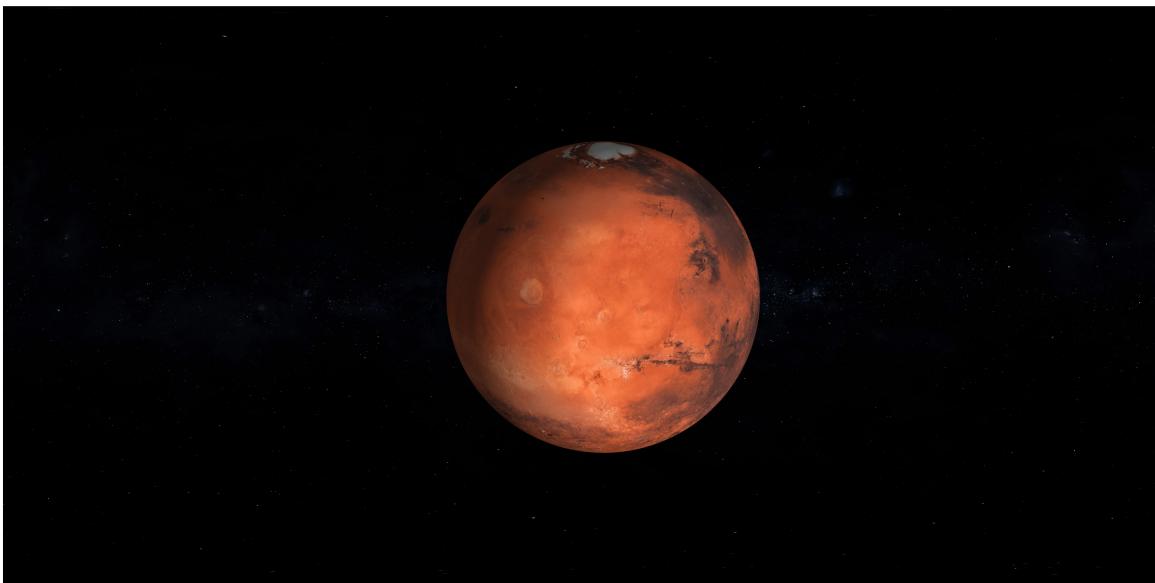
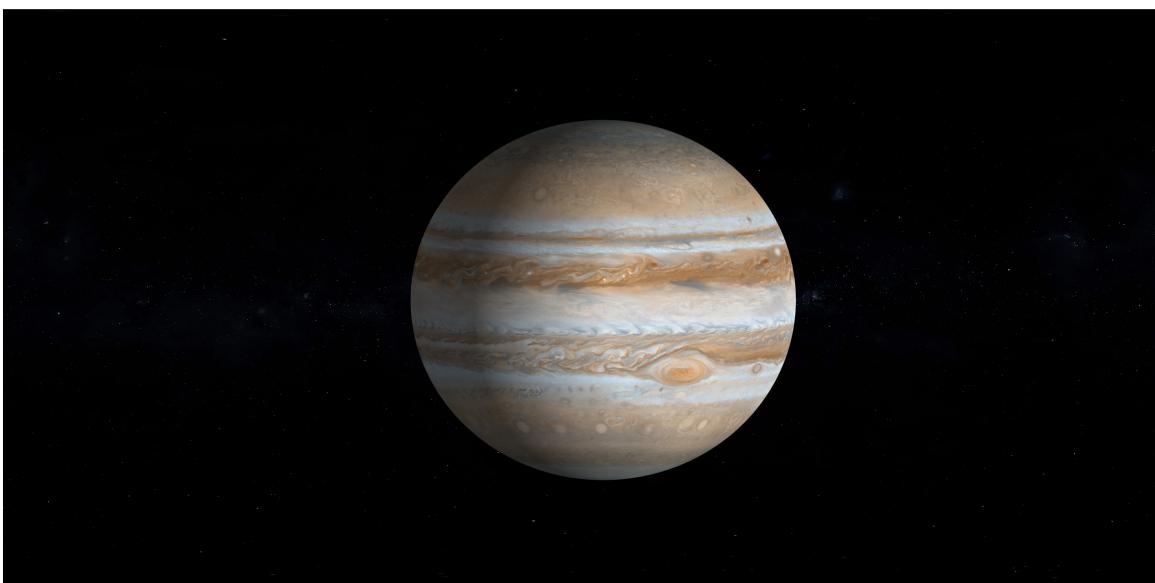
**4.2 Moon****4.3 Sun**

#### 4.4 Mercury

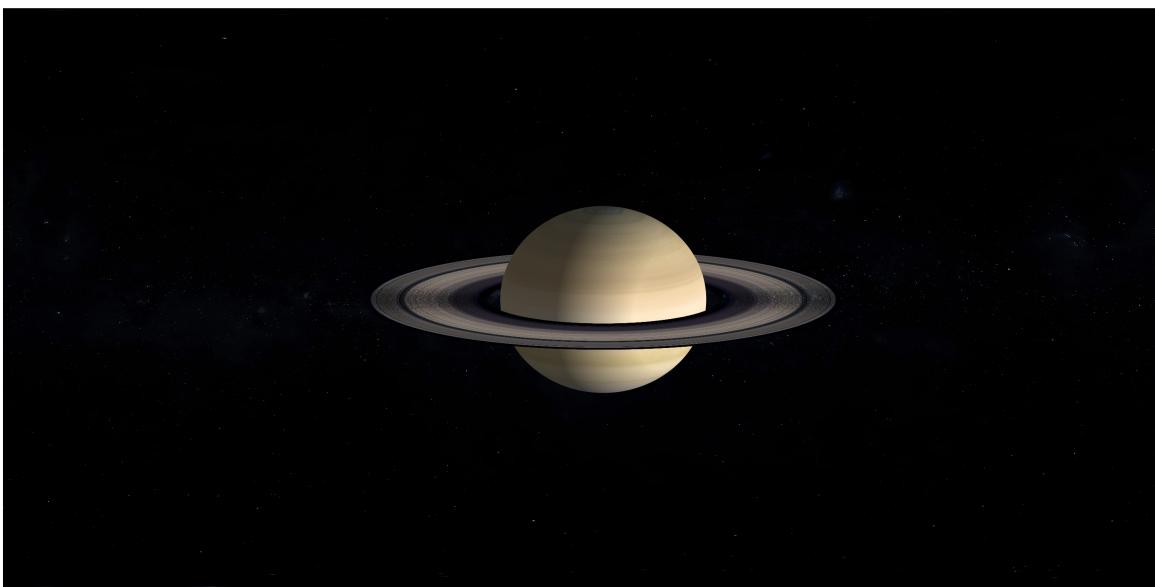


#### 4.5 Venus

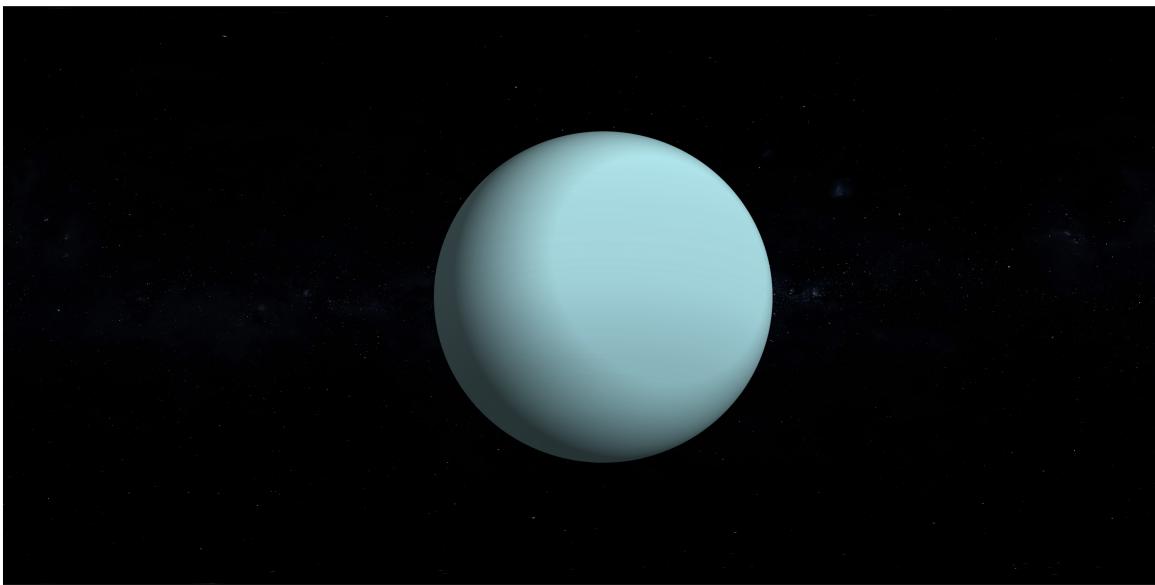


**4.6 Mars****4.7 Jupiter**

## 4.8 Saturn



## 4.9 Uranus



**4.10 Neptune****4.11 Pluto**

## A Data and Constants

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### A.1 Astronomical Data

Planet/Body	Equatorial Radius		Flattening	
	Value [km]	Source	Value	Source
Sun	696000	[13, Table D-5, p. 1043]	0.000 009	[11]
Moon	1738.0	[13, Table D-3, p. 1041]	0.0012	[7]
Mercury	2439.0	[13, Table D-3, p. 1041]	0.0000	[6]
Venus	6052.0	[13, Table D-3, p. 1041]	0.000	[14]
Earth	6378.1363	[13, Table D-3, p. 1041]	0.003 352 813 1	[13, Table D-3, p. 1041]
Mars	3397.2	[13, Table D-3, p. 1041]	0.006 476 30	[13, Table D-3, p. 1041]
Jupiter	71492.0	[13, Table D-4, p. 1042]	0.064 874 4	[13, Table D-4, p. 1042]
Saturn	60268.0	[13, Table D-4, p. 1042]	0.097 962 4	[13, Table D-4, p. 1042]
Uranus	25559.0	[13, Table D-4, p. 1042]	0.022 927 3	[13, Table D-4, p. 1042]
Neptune	24764.0	[13, Table D-4, p. 1042]	0.0171	[13, Table D-4, p. 1042]
Pluto	1151.0	[13, Table D-4, p. 1042]	.0.0	[13, Table D-4, p. 1042]

### A.2 Semi-Minor Axes

For MATLAB's `ellipsoid` function, we need the semi-minor axis,  $b$ , which can be calculated as

$$b = a(1 - f)$$

where  $a$  is the semi-major axis (assumed to be the equatorial radius) and  $f$  is the flattening [3, p. 7-4 (p. 73 in PDF)].

### A.3 Saturn's Rings

Saturn's rings range from 7000 km to 80000 km from the surface of the planet [9].

### A.4 Unit Conversions

#### Kilometers to Astronomical Units [13]:

$$1 \text{ AU} = 149597870 \text{ km} \quad \rightarrow \quad 1 \text{ km} = \frac{1}{149597870} \text{ AU}$$

#### Kilometers to Meters:

$$1 \text{ km} = 1000 \text{ m}$$

**Kilometers to Feet:**

$$1 \text{ km} = \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{100 \text{ cm}}{1 \text{ m}} \right) \left( \frac{1 \text{ in}}{2.54 \text{ cm}} \right) \left( \frac{1 \text{ ft}}{12 \text{ in}} \right) \rightarrow \boxed{1 \text{ km} = \frac{100000}{30.48} \text{ ft}}$$

**Kilometers to Miles:**

$$1 \text{ km} = \left( \frac{100000/30.48 \text{ ft}}{\text{km}} \right) \left( \frac{1 \text{ mi}}{5280 \text{ ft}} \right) \rightarrow \boxed{1 \text{ km} = \frac{100000}{160934.4} \text{ mi}}$$

**Kilometers to Nautical Miles:**

$$1 \text{ nmi} = 1852 \text{ m} = 1.852 \text{ km} \rightarrow \boxed{1 \text{ km} = \frac{1}{1.852} \text{ nmi}}$$

## B Image Sources

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Image	File Name	Source	Copyright/License
Sun	<a href="#">Sun.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Moon	<a href="#">Moon.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Mercury	<a href="#">Mercury.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Venus	<a href="#">Venus.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Earth (Day)	<a href="#">Earth.png</a>	[12]	none [5, 12]
Earth (Night)	<a href="#">Earth Night.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Clouds	<a href="#">Clouds.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Mars	<a href="#">Mars.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Jupiter	<a href="#">Jupiter.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Saturn	<a href="#">Saturn.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Saturn Rings	<a href="#">Saturn Rings.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Uranus	<a href="#">Uranus.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Neptune	<a href="#">Neptune.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0) [1, 10]
Pluto	<a href="#">Pluto.png</a>	[8]	none [8]
Milky Way	<a href="#">Milky Way.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0)
Stars	<a href="#">Stars.png</a>	[10]	CC Attribution 4.0 International (CC BY 4.0)

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## C References for Code

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**3D Earth Example (`earth_example.m`) [4]:**

- Use of `ellipsoid` function to render the Earth.

**Earth-sized Sphere with Topography (`earth_sphere`) [2]:**

- Handling of unit conversions.

## References

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- [1] *Attribution 4.0 International (CC BY 4.0)*. creative commons. <https://creativecommons.org/licenses/by/4.0/>. (accessed: January 27, 2021).
- [2] Will Campbell. *Earth-sized Sphere with Topography*. MATLAB Central File Exchange. <https://www.mathworks.com/matlabcentral/fileexchange/27123-earth-sized-sphere-with-topography>. (accessed: January 22, 2021).
- [3] *Department of Defense World Geodetic System 1984*. Tech. rep. NIMA TR8350.2. <https://apps.dtic.mil/sti/pdfs/AD1000581.pdf>. National Imagery and Mapping Agency, 2004.
- [4] Ryan Gray. *3D Earth Example*. MATLAB Central File Exchange. <https://www.mathworks.com/matlabcentral/fileexchange/13823-3d-earth-example>. (accessed: January 22, 2021).
- [5] *Image Use Policy*. NASA visible earth. <https://visibleearth.nasa.gov/image-use-policy>. (accessed: January 23, 2021).
- [6] *Mercury Fact Sheet*. NASA. <https://nssdc.gsfc.nasa.gov/planetary/factsheet/mercuryfact.html>. (accessed: January 22, 2021).
- [7] *Moon*. Wikipedia. <https://en.wikipedia.org/wiki/Moon>. (accessed: January 22, 2021).
- [8] *Pluto Color Map*. NASA Jet Propulsion Laboratory. <https://www.jpl.nasa.gov/images/pluto-color-map/>. (accessed: January 23, 2021).
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- [10] *Solar Textures*. Solar System Scope. <https://www.solarsystemscope.com/textures/>. (accessed: January 22, 2021).
- [11] *Sun*. Wikipedia. <https://en.wikipedia.org/wiki/Sun>. (accessed: January 22, 2021).
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- [13] David A. Vallado. *Fundamentals of Astrodynamics and Applications*. 4<sup>th</sup>. Hawthorne, CA: Microcosm Press, 2013.
- [14] *Venus Fact Sheet*. NASA. <https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html>. (accessed: January 22, 2021).