

3D Earth and Celestial Bodies

MATLAB Implementation

Tamas Kis | kis@stanford.edu

TAMAS KIS
<https://github.com/tamaskis>

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planet3D

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

Syntax

```
planet3D(planet,position,gmst,reference_plane,units,transparency)
```

NOTE: All parameters except for `planet` are optional. If you “skip over” parameters, you need to use empty bracket (i.e. “[]”) as placeholders, otherwise you can omit parameters altogether. For example, if you don’t want to specify `position`, but do want to specify `units`, then you would use the syntax `planet3D(planet,[],[],[],units)`. Alternatively, if we wanted to specify just the `position`, we could use the syntax `planet3D(planet,position)`.

NOTE: Use the `background` function (see Section) 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,gmst,reference_plane,units,transparency)` 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).
<code>gmst (optional)</code>	Specifies the Greenwich mean sidereal time (the angle from the direction of the vernal equinox to 0 degrees longitude, measured in degrees).
<code>reference_plane (optional)</code>	Specifies which reference plane the celestial body is drawn with respect to. If specified as ' <code>equatorial</code> ', the reference plane is taken to be the equatorial plane of the celestial body. If specified as ' <code>ecliptic</code> ', the celestial body will be tilted by the obliquity (i.e. the angle between the ecliptic plane and the equatorial plane).
<code>units (optional)</code>	Specifies the units the celestial body should be drawn in. Units available are ' <code>km</code> ', ' <code>AU</code> ', ' <code>m</code> ', ' <code>ft</code> ', ' <code>mi</code> ', and ' <code>nmi</code> '.
<code>transparency (optional)</code>	Specifies how transparent the celestial body is (0 for 100% transparency, 1 for 100% solid).

Links

MATLAB® Central's File Exchange:

<https://www.mathworks.com/matlabcentral/fileexchange/86483-3d-earth-and-celestial-bodies-planet3d>

GitHub®:

<https://github.com/tamaskis/planet3D-MATLAB>

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**'.

Links

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<https://github.com/tamaskis/planet3D-MATLAB>

Example Plots

Celestial Bodies on Milky Way Background

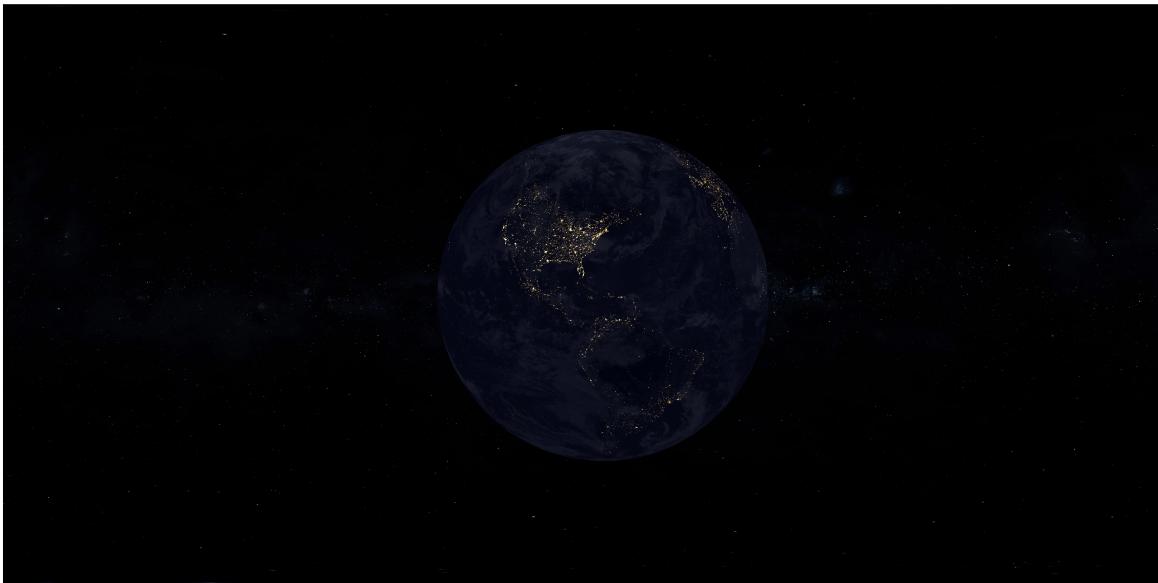
Earth (With Clouds):



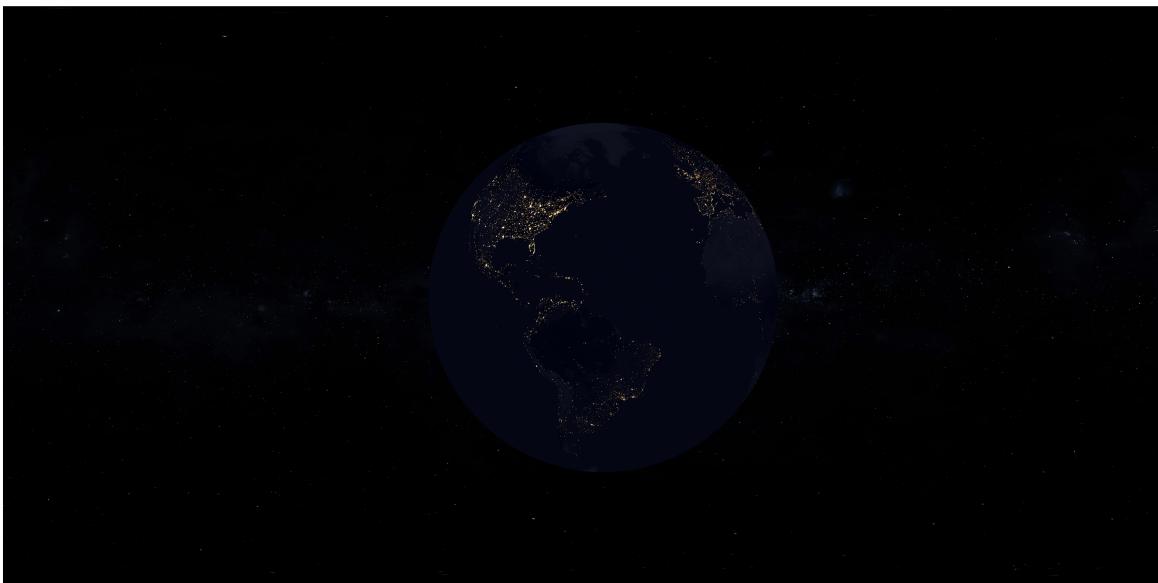
Earth (No Clouds):



Earth (Night, With Clouds):



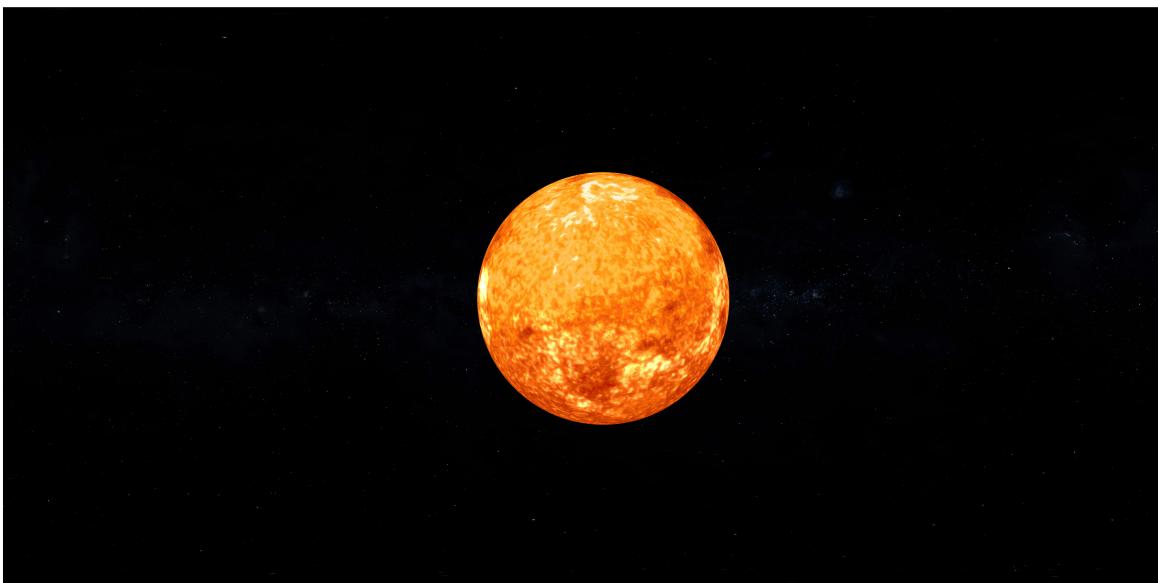
Earth (Night, No Clouds):



Moon:



Sun:



Mercury:



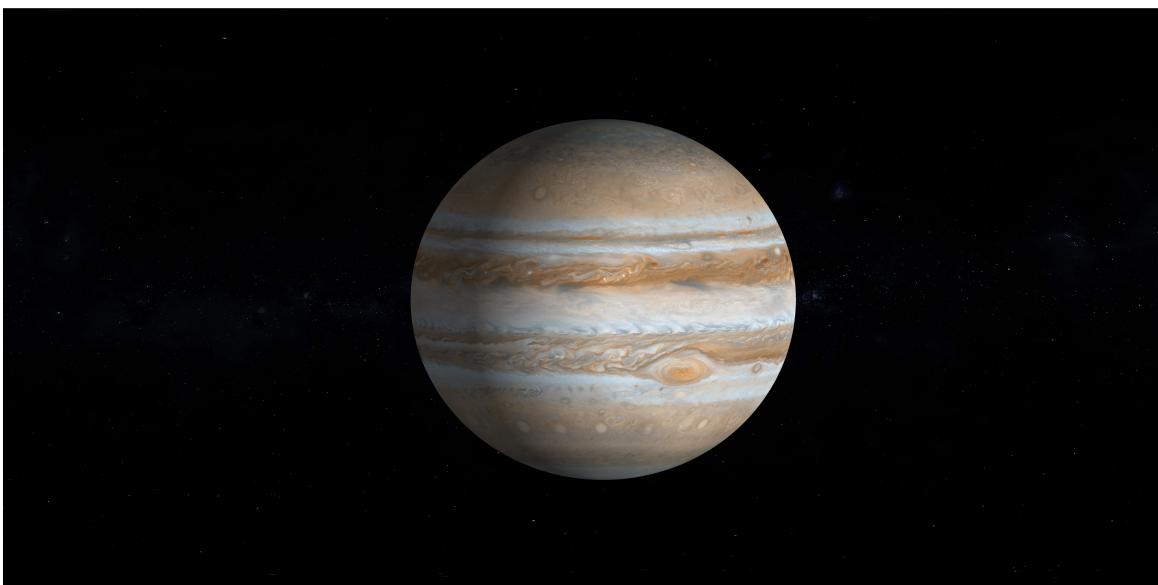
Venus:



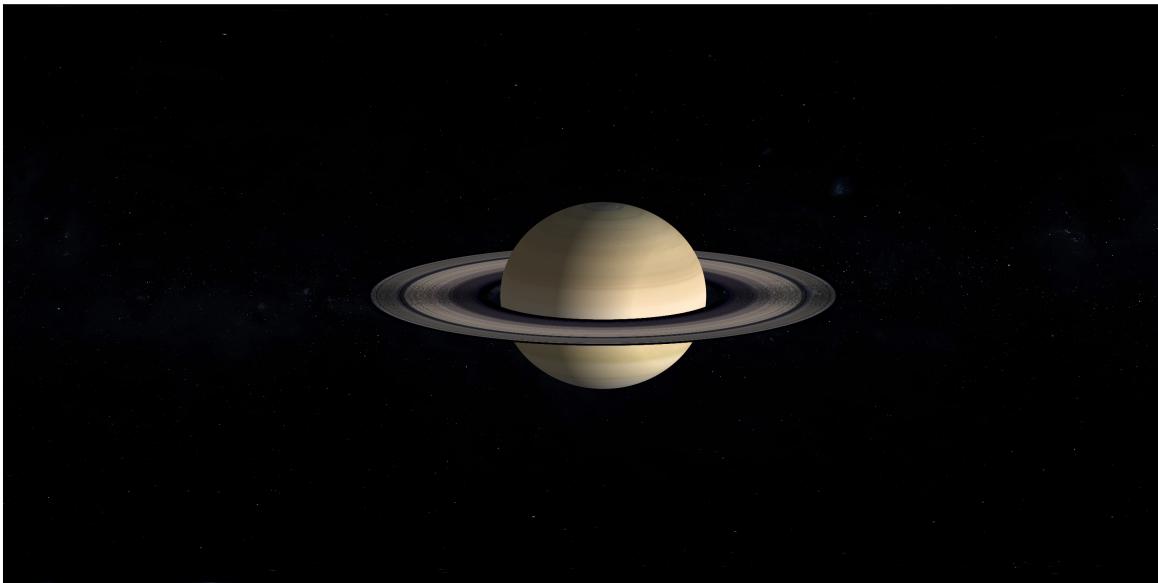
Mars:



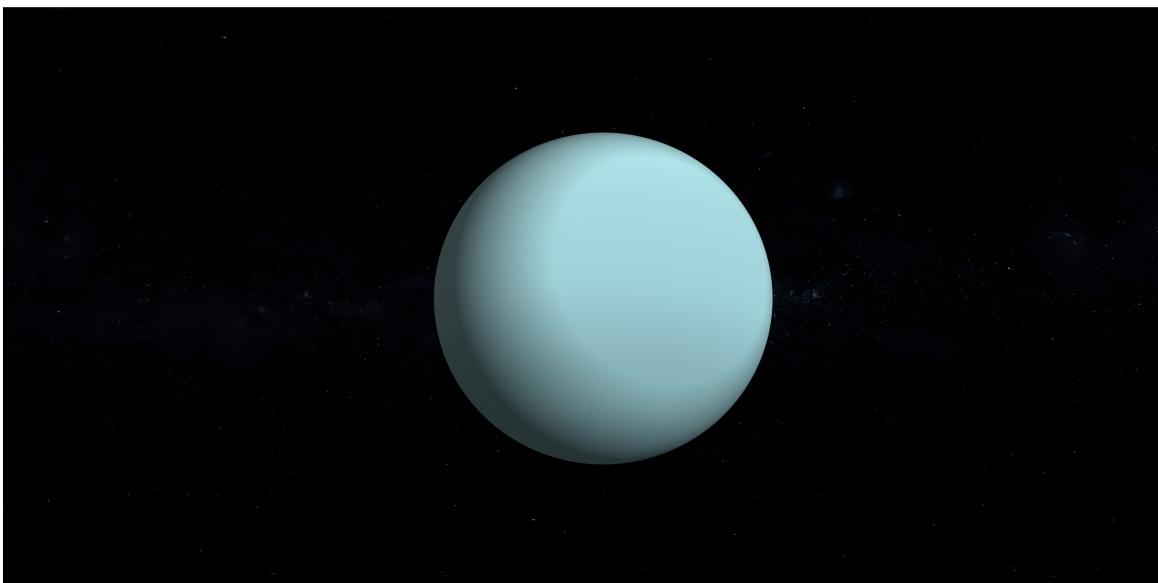
Jupiter:



Saturn:



Uranus:



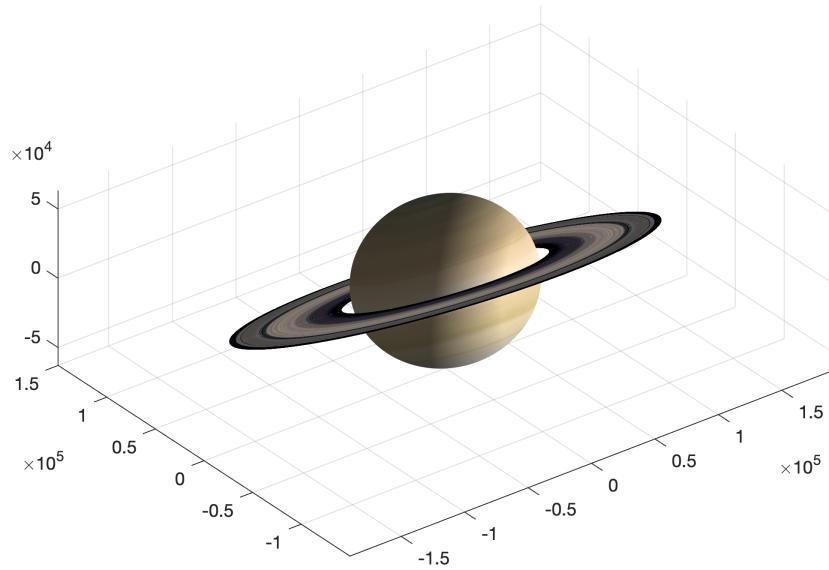
Neptune:



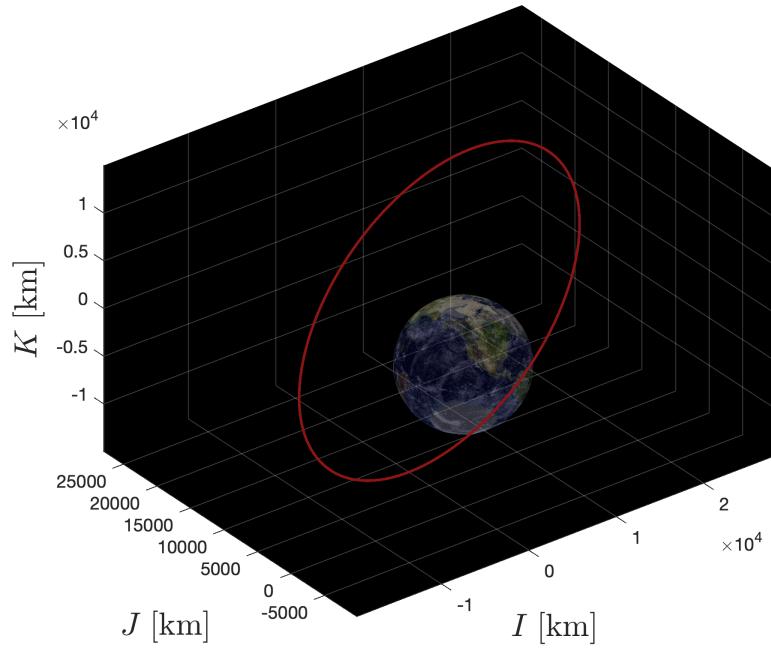
Pluto:



Saturn in Ecliptic Plane on White Background with Grid Lines



Elliptical Trajectory Around Transparent Earth on Black Background with Grid Lines



Data and Constants

Astronomical Data

Planet/Body	Equatorial Radius		Flattening		Obliquity	
	Value [km]	Source	Value	Source	Value [°]	Source
Sun	696000	[13]*	0.000 009	[11]	0	-
Moon	1738.0	[13]**	0.0012	[7]	6.68	[13]**
Mercury	2439.0	[13]**	0.0000	[6]	0.0	[13]**
Venus	6052.0	[13]**	0.000	[14]	177.3	[13]**
Earth	6378.1363	[13]**	0.003 352 813 1	[13]**	23.45	[13]**
Mars	3397.2	[13]**	0.006 476 30	[13]**	25.19	[13]**
Jupiter	71492.0	[13]***	0.064 874 4	[13]***	3.12	[13]***
Saturn	60268.0	[13]***	0.097 962 4	[13]***	26.73	[13]***
Uranus	25559.0	[13]***	0.022 927 3	[13]***	97.86	[13]***
Neptune	24764.0	[13]***	0.0171	[13]***	29.56	[13]***
Pluto	1151.0	[13]***	0.0	[13]***	118.0	[13]***

*Table D-5, p. 1043

**Table D-3, p. 1041

***Table D-4, p. 1042

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)].

Saturn's Rings

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

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:

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

Kilometers to Miles:

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

Kilometers to Nautical Miles:

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

Image Sources

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

References for Code

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

- [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).
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- [13] David A. Vallado. *Fundamentals of Astrodynamics and Applications*. 4th. Hawthorne, CA: Microcosm Press, 2013.
- [14] *Venus Fact Sheet*. NASA. <https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html>. (accessed: January 22, 2021).