

# **System 1 Ephemeris Tool Operation for Artemis II Tracking at the DSES Plishner Site**

Glenn Davis, Lewis Putnam, Phil Gage

18 March 2026

# Why the Ephemeris Tool for tracking the Artemis II Spacecraft

- The Current System 1 software does not currently provide the operator a method for tracking Deep Space Objects automatically.
- When the System 1 team became aware of the JPL Horizons website it was determine that we could rapidly create a tool that would provide manual pointing data for the operator.
- The Ephemeris Tool was created to read ephemeris data outputted from the JPL Horizons Website. With this data, the Ephemeris Tool could prompt the operator to cut and paste position data from the tool into the System 1 Automatic Tracking display at the appropriate time for tracking the Artemis II spacecraft.
- We hoped to complete the tool prior to the February launch dates. It is now ready for the March launch dates.

# JPL Horizons Web Application

- Go to the NASA JPL Horizons Web App site in your browser:
  - <https://ssd.jpl.nasa.gov/horizons/app.html#/>
- When you show Horizons in your web browser you can use the Edit buttons to adjust the Settings (as shown below) which are saved in your browser data. Later you may need to update only the Time Specification values for each period of interest. The Save/Load Settings button can be used to save and load named sets of Settings to your browser data.
- Press Generate Ephemeris and Download Results to generate and download a "horizons\_results.txt" ephemeris file to your Downloads directory. The file name may have a version number in parentheses.

# JPL Horizons Setup (1 Type: Observer Table)

The screenshot shows the JPL Horizons System web application interface. The browser address bar displays `https://ssd.jpl.nasa.gov/horizons/app.html#/`. The page has a dark header with "Home" and a breadcrumb trail "Home / Tools / Horizons System". The main heading is "Horizons System" with navigation tabs for "About", "App", "Manual", "Tutorial", "Time Spans", and "News". The section "Horizons Web Application" contains a "Save/Load Settings..." button and five configuration items:

- 1 Ephemeris Type: **Observer Table**
- 2 **Edit** Target Body: **Moon [Luna]**
- 3 **Edit** Observer Location: **-103.156375°E, 38.380847°N, 1308 m**
- 4 **Edit** Time Specification: Start=**2026-03-12** UT , Stop=**2026-03-15**, Step=**15** (minutes)
- 5 **Edit** Table Settings: *custom*

Below the settings is a "Generate Ephemeris" button and a section titled "Ephemeris Results" with a "Download Results" button. The results area shows a table header:

```
*****  
Revised: July 31, 2013           Moon / (Earth)           301
```

# 2 Target Body (Artemis II after launch)

## Specify the Target Body

Choose a method for specifying the target body:

Search for a specified body

### Lookup the Specified Body

Artemis

Search

Search all available bodies (default)

To restrict your search to only small-bodies or only major-bodies, use the pulldown menu to the right of the **Search** button:

Show Examples

### Select from the List of 4 Matching Bodies

MB: THEMIS-B (spacecraft) (2007-004B)

**MB: Artemis I (spacecraft) (2022-156A)**

MB: THEMIS-C (spacecraft) (2007-004C)

SB: 105 Artemis (A868 SA)

Select Indicated Body

# 3 Observer Location (Haswell 60-foot dish)

## Specify Observer Location

Current Location: Geocentric [code: 500]

Choose a method:

Specify Coordinates

### Specify Observer Location using Body Coordinates

Show Examples

Coordinate Body: **Earth** [change](#)

Type of coordinates: Geodetic Coordinates

longitude:  (deg)

latitude:  (deg)

altitude:

Use Specified Coordinates

# 4 Time Specification (use half the desired Step size)

## Time Specification

Choose a method for specifying output times:

Specify time span ▾

### Specify a Time Span

Start time: ? 2026-03-12

B.C. 9999-03-20 00:00 (min. for current target body)

Stop time: ? 2026-03-15

A.D. 9999-12-31 12:00 (max. for current target body)

Step size: ? 15 minutes ▾

Optionally, select one of the presets below to set the time-span from today to the indicated number of days later at 1-day steps.

10 day 30 day 60 day

Use Specified Time Span

# 5 Table Settings

- Observer Table Settings:
  - Option 1 Astrometric RA & DEC must be checked.
  - Option 4 Apparent AZ & EL should be checked for the Ephemeris Tool Elevation data.
- Additional Table Settings:
  - Angle Format must be set to decimal degrees.
  - Do not use the Cutoff settings, they may cause tool errors.
- Press Use Specified Settings to save changes in your browser data.

# Observer Table Settings

## Observer Table Settings

Optionally preset observer quantities selection using one of the following:

Default Planets Satellites Small-bodies All None

- |                                                                    |                                                                          |                                                                        |
|--------------------------------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------|
| 1. <input checked="" type="checkbox"/> Astrometric RA & DEC        | 17. <input type="checkbox"/> North Pole position angle & distance        | 33. <input type="checkbox"/> Galactic longitude & latitude             |
| * 2. <input type="checkbox"/> Apparent RA & DEC                    | 18. <input type="checkbox"/> Heliocentric ecliptic lon. & lat.           | 34. <input type="checkbox"/> Local apparent SOLAR time                 |
| 3. <input type="checkbox"/> Rates; RA & DEC                        | 19. <input type="checkbox"/> Heliocentric range & range-rate             | 35. <input type="checkbox"/> Earth->obs. site light-time               |
| * 4. <input checked="" type="checkbox"/> Apparent AZ & EL          | 20. <input checked="" type="checkbox"/> Observer range & range-rate      | > 36. <input type="checkbox"/> RA & DEC uncertainty                    |
| 5. <input type="checkbox"/> Rates; AZ & EL                         | 21. <input type="checkbox"/> One-way (down-leg) light-time               | > 37. <input type="checkbox"/> Plane-of-sky error ellipse              |
| 6. <input type="checkbox"/> Satellite X & Y, pos. angle            | 22. <input type="checkbox"/> Speed wrt Sun & observer                    | > 38. <input type="checkbox"/> POS uncertainty (RSS)                   |
| 7. <input type="checkbox"/> Local apparent sidereal time           | 23. <input checked="" type="checkbox"/> Sun-Observer-Target ELONG angle  | > 39. <input type="checkbox"/> Range & range-rate 3-sigmas             |
| 8. <input type="checkbox"/> Airmass & extinction                   | 24. <input checked="" type="checkbox"/> Sun-Target-Observer ~PHASE angle | > 40. <input type="checkbox"/> Doppler & delay 3-sigmas                |
| 9. <input checked="" type="checkbox"/> Visual mag. & Surface Brght | 25. <input type="checkbox"/> Target-Observer-Moon angle/ Illum%          | 41. <input type="checkbox"/> True anomaly angle                        |
| 10. <input type="checkbox"/> Illuminated fraction                  | 26. <input type="checkbox"/> Observer-Primary-Target angle               | 42. <input type="checkbox"/> Local apparent hour angle                 |
| 11. <input type="checkbox"/> Defect of illumination                | 27. <input type="checkbox"/> Sun-Target radial & -vel pos. angle         | 43. <input type="checkbox"/> PHASE angle & bisector                    |
| 12. <input type="checkbox"/> Satellite angular separ/vis.          | 28. <input type="checkbox"/> Orbit plane angle                           | 44. <input type="checkbox"/> Apparent longitude Sun (L_s)              |
| 13. <input type="checkbox"/> Target angular diameter               | 29. <input type="checkbox"/> Constellation ID                            | * 45. <input type="checkbox"/> Inertial apparent RA & DEC              |
| 14. <input type="checkbox"/> Observer sub-lon & sub-lat            | 30. <input type="checkbox"/> Delta-T (TDB - UT)                          | 46. <input type="checkbox"/> Rate: Inertial RA & DEC                   |
| 15. <input type="checkbox"/> Sun sub-longitude & sub-latitude      | * 31. <input type="checkbox"/> Observer ecliptic lon. & lat.             | 47. <input checked="" type="checkbox"/> Sky motion: rate & angles      |
| 16. <input type="checkbox"/> Sub-Sun position angle & distance     | 32. <input type="checkbox"/> North pole RA & DEC                         | 48. <input checked="" type="checkbox"/> Lunar sky-brightness & sky SNR |

### Notes:

- \* affected by optional atmospheric refraction setting
- > statistical value that uses orbit covariance if available

# Additional Table Settings

## Additional Table Settings

Reference frame: ?	ICRF
Date/time format: ?	calendar format
Calendar type: ?	Mixed
Time digits: ?	HH:MM
Angle format: ?	decimal degrees
Refraction model: ?	no refraction (airless)
Range units: ?	astronomical units (au)
Suppress range-rate: ?	<input type="checkbox"/>
Elevation cutoff: ?	<input type="text"/> (deg) [ -90 to 90 ]
Skip daylight: ?	<input type="checkbox"/>
Airmass cutoff: ?	<input type="text"/> [ 1.0 to 38.0 ]
Hour-angle cutoff: ?	<input type="text"/> (angular hours) [ 0.0 to 12.0 ]
Solar elongation cutoff: ?	<input type="text"/> : <input type="text"/> (deg) [min:max], min= 0.0 to 180.0 , max= min to 180.0
Angular rate cutoff: ?	<input type="text"/> (arcsec/h) [ 0.0 to 100000.0 ]
Extra precision: ?	<input type="checkbox"/> —output additional digits for RA/Dec quantities
RTS flag: ?	disabled —output only at target rise/transit/set
CSV format: ?	<input type="checkbox"/>
Object summary: ?	<input checked="" type="checkbox"/>

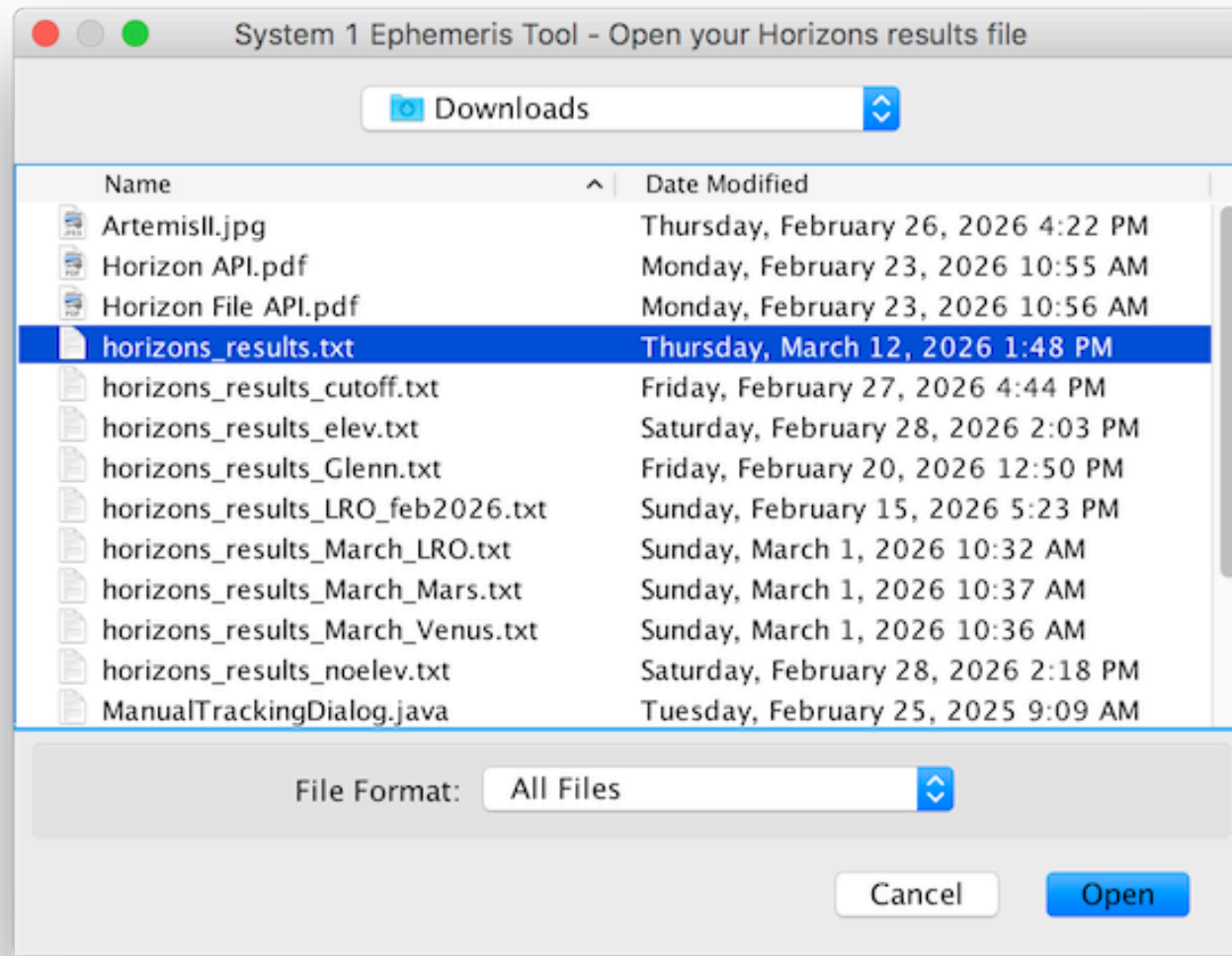
Use Specified Settings

Reset to Defaults

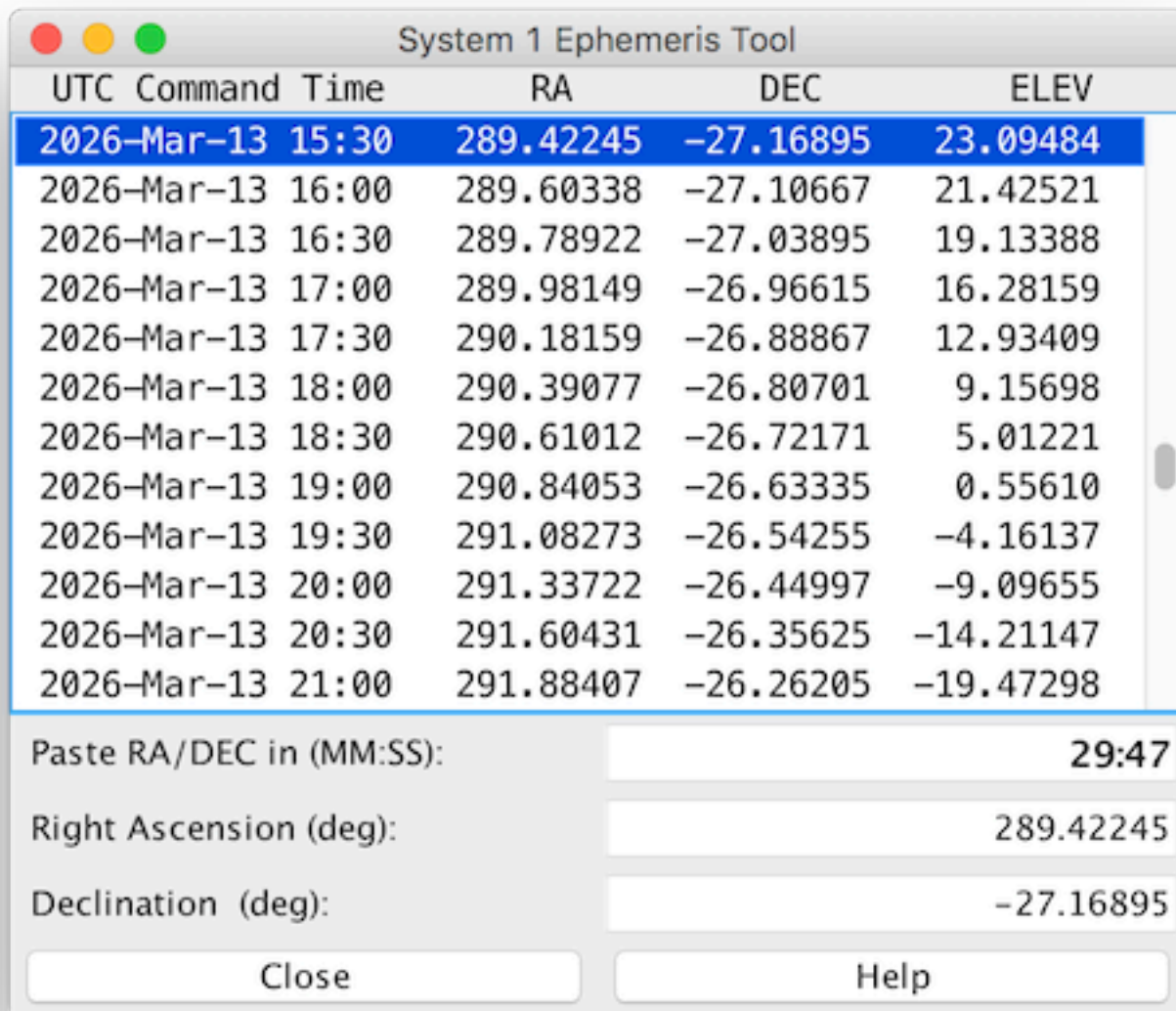
# System 1 Ephemeris Tool

- Run the standalone Ephemeris Tool by double-clicking the screen icon.
- The tool initially displays a File Chooser that starts in the operator's Downloads directory to select the desired Horizons results file for tracking.
- The tool main display shows a list of ephemeris RA/DEC positions and elevations (degrees) above the horizon. The next position to be commanded is highlighted and shown in the RA, DEC fields at the bottom. The Paste RA/DEC field is a countdown to the RA/DEC command time, explained below. Click the left mouse button on the list anywhere to find the current highlighted row after scrolling.

# System 1 Ephemeris Tool File Chooser



# System 1 Ephemeris Tool



The screenshot shows a window titled "System 1 Ephemeris Tool" with a table of data and input fields below it. The table has five columns: UTC, Command, Time, RA, DEC, and ELEV. The first row is highlighted in blue. Below the table are three input fields for "Paste RA/DEC in (MM:SS)", "Right Ascension (deg)", and "Declination (deg)", each with a corresponding value. At the bottom are "Close" and "Help" buttons.

UTC	Command	Time	RA	DEC	ELEV
2026-Mar-13	15:30		289.42245	-27.16895	23.09484
2026-Mar-13	16:00		289.60338	-27.10667	21.42521
2026-Mar-13	16:30		289.78922	-27.03895	19.13388
2026-Mar-13	17:00		289.98149	-26.96615	16.28159
2026-Mar-13	17:30		290.18159	-26.88867	12.93409
2026-Mar-13	18:00		290.39077	-26.80701	9.15698
2026-Mar-13	18:30		290.61012	-26.72171	5.01221
2026-Mar-13	19:00		290.84053	-26.63335	0.55610
2026-Mar-13	19:30		291.08273	-26.54255	-4.16137
2026-Mar-13	20:00		291.33722	-26.44997	-9.09655
2026-Mar-13	20:30		291.60431	-26.35625	-14.21147
2026-Mar-13	21:00		291.88407	-26.26205	-19.47298

Paste RA/DEC in (MM:SS):

Right Ascension (deg):

Declination (deg):

# System 1 AstroGuide Coordinate Converter

- Start the System 1 software and AstroGuide as usual. From the AstroGuide Window menu select Coordinate Converter and Automatic Tracking.
- The displayed Ephemeris Tool RA and DEC values must be copied (with Control-C) and pasted (with Control-V) separately to the Coordinate Converter RA (degrees) and DEC (degrees) fields each time well before the Ephemeris Tool Paste countdown reaches zero.
- Press Convert (to update the HMS/DMS values needed for the mount) and press Copy RA/DEC.

# System 1 AstroGuide Coordinate Converter

Coordinate Converter (J2000)

Enter RA/DEC in Degrees  
 Enter RA/DEC in Hours, Minutes, Seconds

Convert RA/DEC to Other Coordinates  
 Convert AZ/EL to Other Coordinates  
 Convert GLAT/GLONG to Other Coordinates

RA (degrees):	<input type="text" value="289.42245"/>	AZ (degrees):	<input type="text" value="185.0445"/>
DEC (degrees):	<input type="text" value="-27.16895"/>	EL (degrees):	<input type="text" value="24.3189"/>
RA (hours, mins, secs):	<input type="text" value="19"/> <input type="text" value="17"/> <input type="text" value="41.4"/>	GAL LAT (degrees):	<input type="text" value="-17.3800"/>
DEC (degs, mins, secs):	<input type="text" value="-27"/> <input type="text" value="10"/> <input type="text" value="8.2"/>	GAL LONG (degrees):	<input type="text" value="10.7693"/>

Seconds Offset from Current Time (-86400.0 to 86400.0 seconds):

Conversion Time (UTC):

Conversion Time (Julian Date):

# System 1 AstroGuide

## Automatic Tracking

- When the Ephemeris Tool Paste RA/DEC in (MM:SS) countdown field is near zero press Stop Tracking, Paste RA/DEC and Start Slewing. The Tool countdown field turns yellow the last two minutes to help alert the operator.
- Optionally, the Coordinate Converter Set Selected Position button will display an X symbol at the commanded RA/DEC on AstroGuide and should be pressed every time the RA/DEC is pasted into the Automatic Tracking window.
- Repeat the process for each ephemeris RA/DEC position to continue tracking.

# System 1 AstroGuide Automatic Tracking

Automatic Tracking

Automatic Tracking | Scan Pattern | SDR Receiver | Mount Calibration

Input Target

RA (hour,min,sec): 19 17 41  
DEC (deg,min,sec): -27 10 8  
AZ (degrees): 186.7930 EL (degrees): 24.1736  
Satellite Number: 0 Find Satellite Paste Satellite  
Track RA/DEC Audible Paste RA/DEC

Status

	Azimuth	Elevation
Mount Rate (deg/sec):	0.0000	0.0000
Target Rate (deg/sec):	0.0041	-0.0004
Mount Position (deg):	186.7017	24.1754
Target Position (deg):	186.7930	24.1736
Position Error (deg):	-0.0914	0.0018
Recommended Switch:	Neutral	Neutral

Start Tracking Stop Tracking Sources Close Help

# System 1 Ephemeris Tool Operation Summary

- JPL Horizons Web App (<https://ssd.jpl.nasa.gov/horizons/app.html#/>)
  1. If needed, check Settings, press Generate Ephemeris, Download Results
- System 1 Ephemeris Tool
  2. Choose the appropriate generated Horizons results file
  3. Copy the Right Ascension value using left mouse button and Control-C
  5. Copy the Declination value using left mouse button and Control-C
- System 1 Software
  4. Paste to RA (degrees) in Coordinate Converter using mouse and Control-V
  6. Paste to DEC (degrees) in Coordinate Converter using mouse and Control-V
  7. Press Convert, Copy RA/DEC in Coordinate Converter
  8. When Tool countdown is zero, in Automatic Tracking press Stop Tracking, Paste RA/DEC, Start Slewing
  9. Go to 3, repeat until done