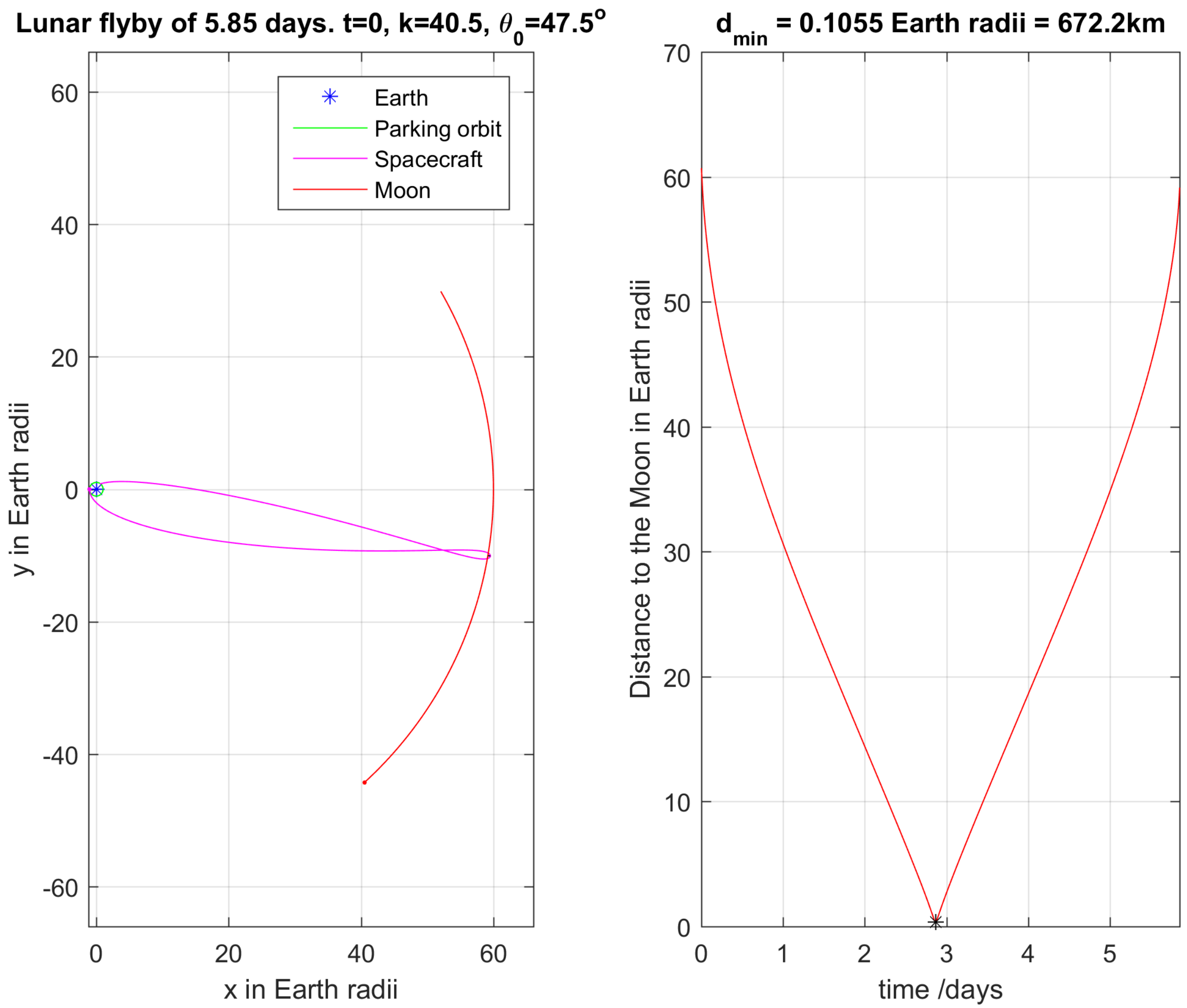
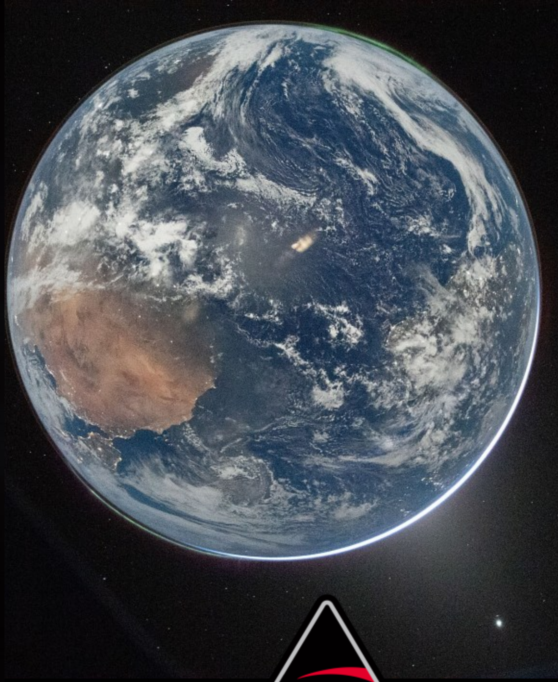


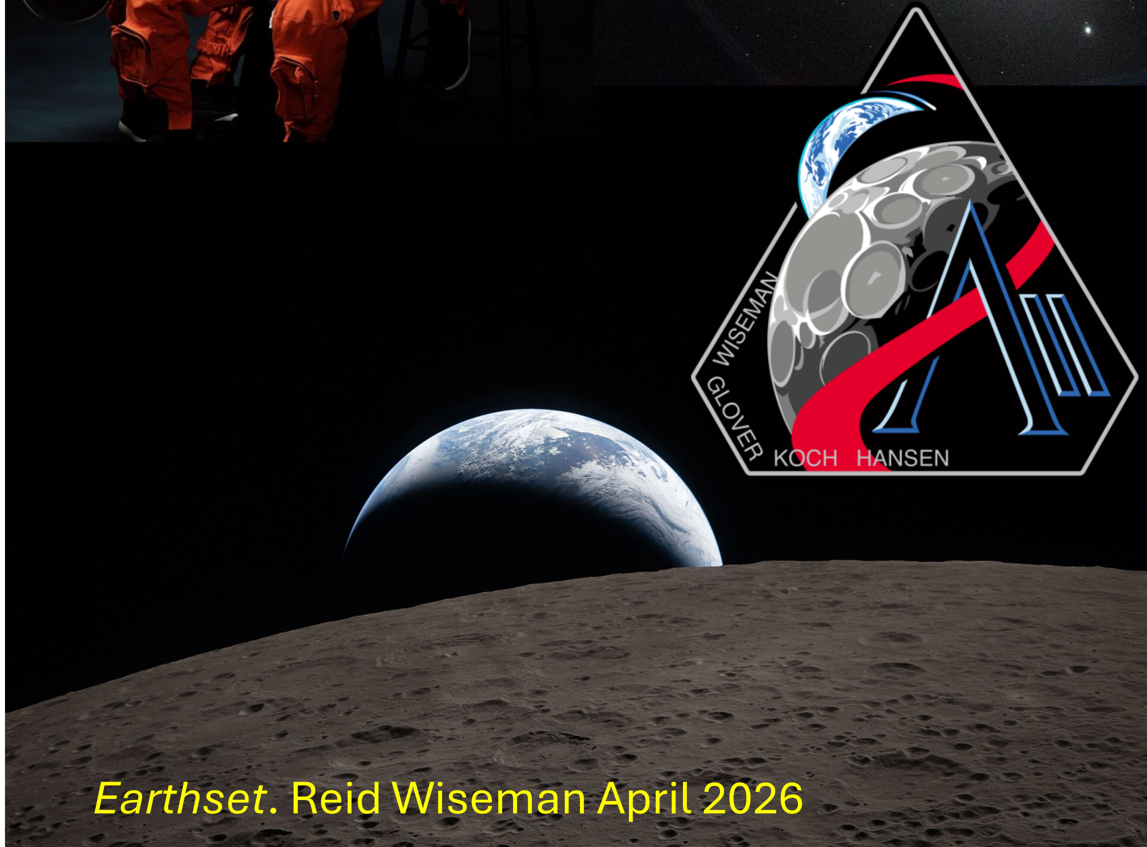
Artemis II (approximate!) trajectory simulation

AF. April 2026

https://en.wikipedia.org/wiki/Artemis_II

https://www.nasa.gov/mission/artemis-ii/





Earthset. Reid Wiseman April 2026


ARTEMIS
BOARDING NOW
National Aeronautics and Space Administration
M2M2026238900AII
BOARDING PASS: ARTEMIS II
Spideog Wikipedia
ROCKET
SLS (SPACE LAUNCH SYSTEM)
LAUNCH SITE
KENNEDY SPACE CENTER, FLORIDA
SPACECRAFT
ORION
DESTINATION
AROUND THE MOON
WISEMAN
GLOVER
KOCH
HANSEN
COMMANDER: REID WISEMAN
PILOT: VICTOR GLOVER
MISSION SPECIALIST: CHRISTINA KOCH
MISSION SPECIALIST: JEREMY HANSEN
MILEAGE EARNED: 685,000 MILES


Christina Koch (USA)
Jeremy Hansen (Canada)
Reid Wiseman (Capt. USA)
Victor Glover (USA)


NASA


Launch from
complex 39B at
NASA’s Kennedy
Space Center
on 1st April 2026

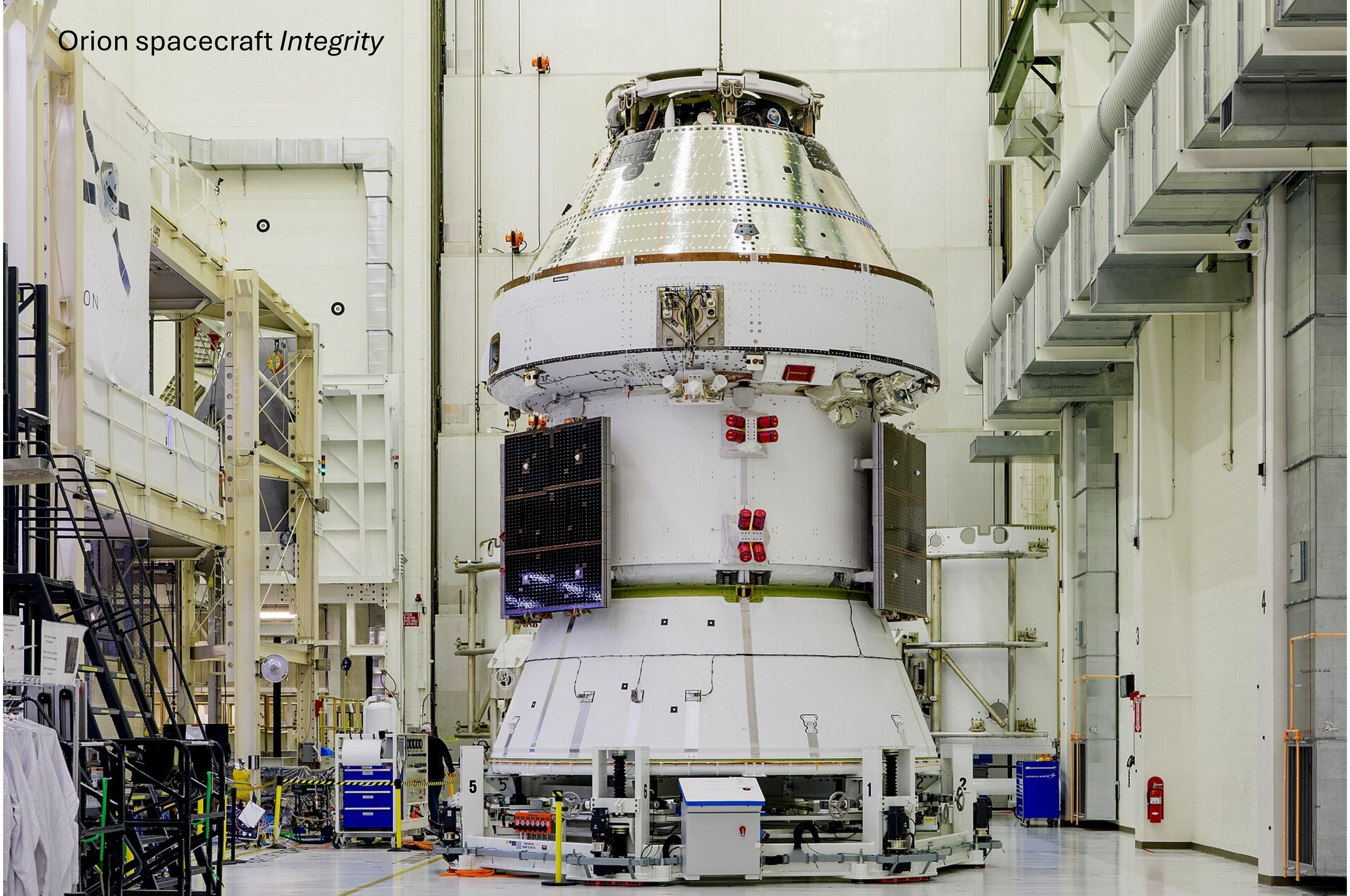

Launch abort
system jettisoned

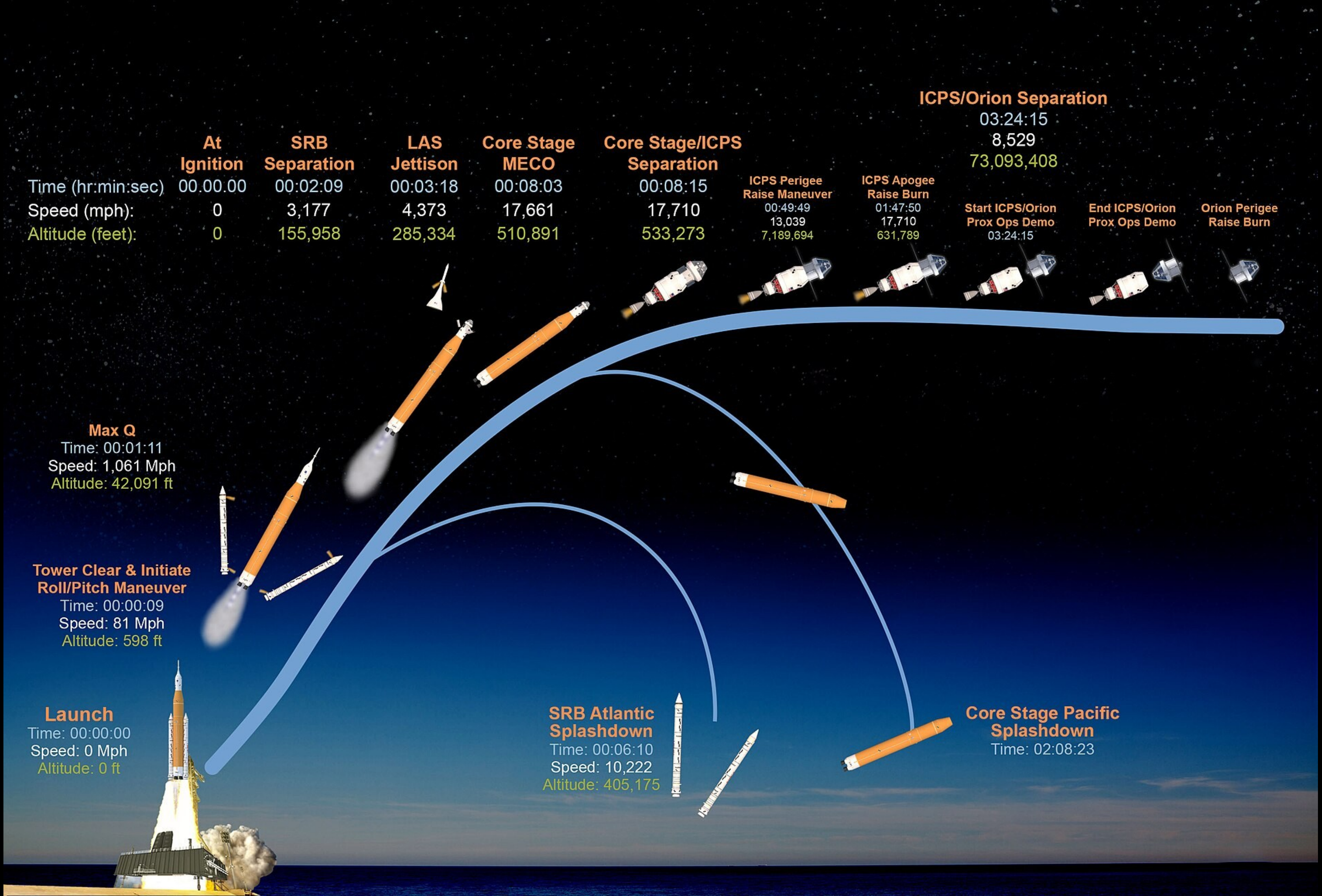

Splashdown on
10th April 2026

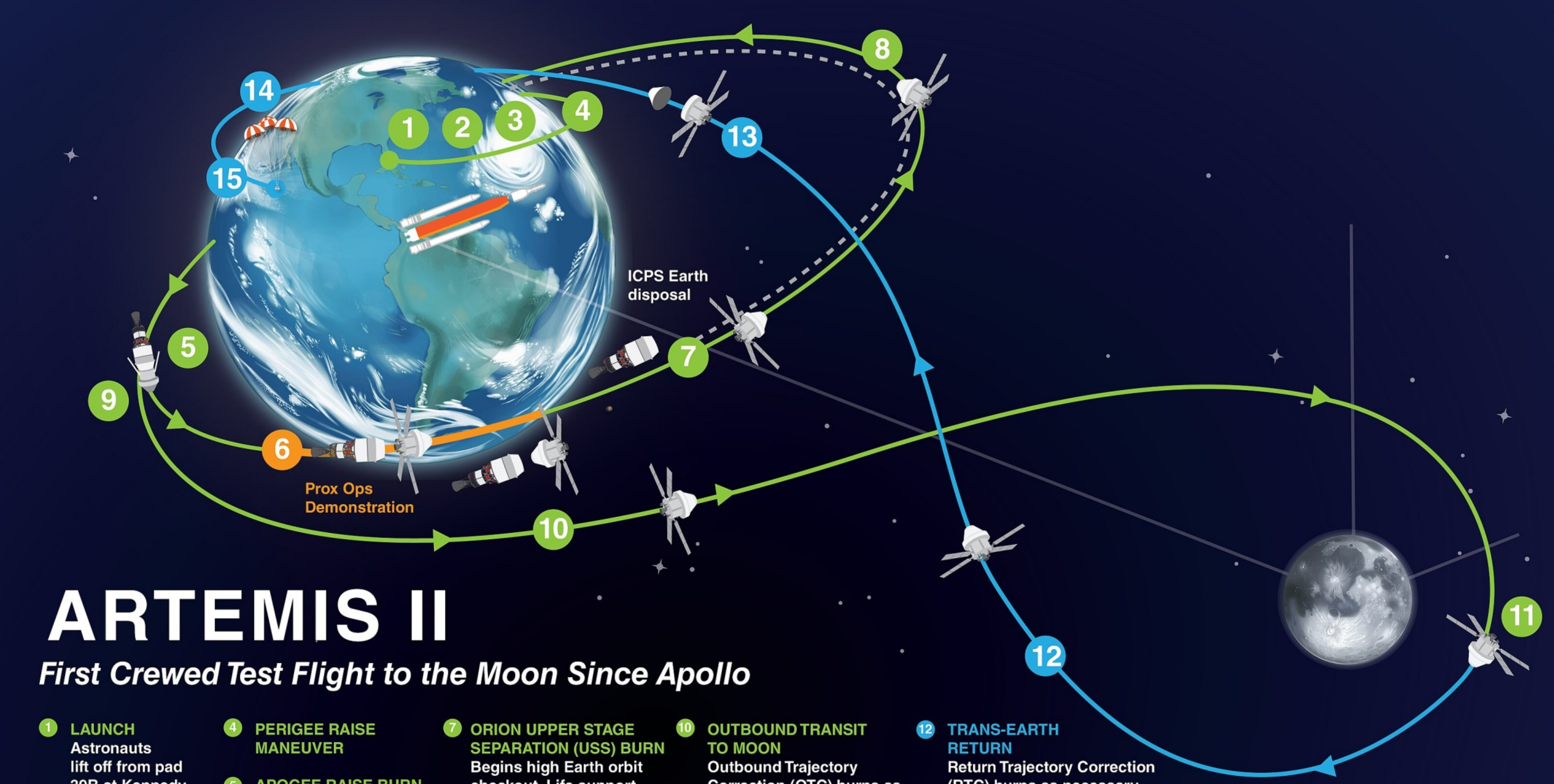
Integrity spacecraft approaches the moon during the Artemis 2 mission. April 1-10 2026.

https://en.wikipedia.org/wiki/Artemis_II#/media/File:Orion_in_the_Spotlight_(art002e009566).jpg

Orion spacecraft *Integrity*



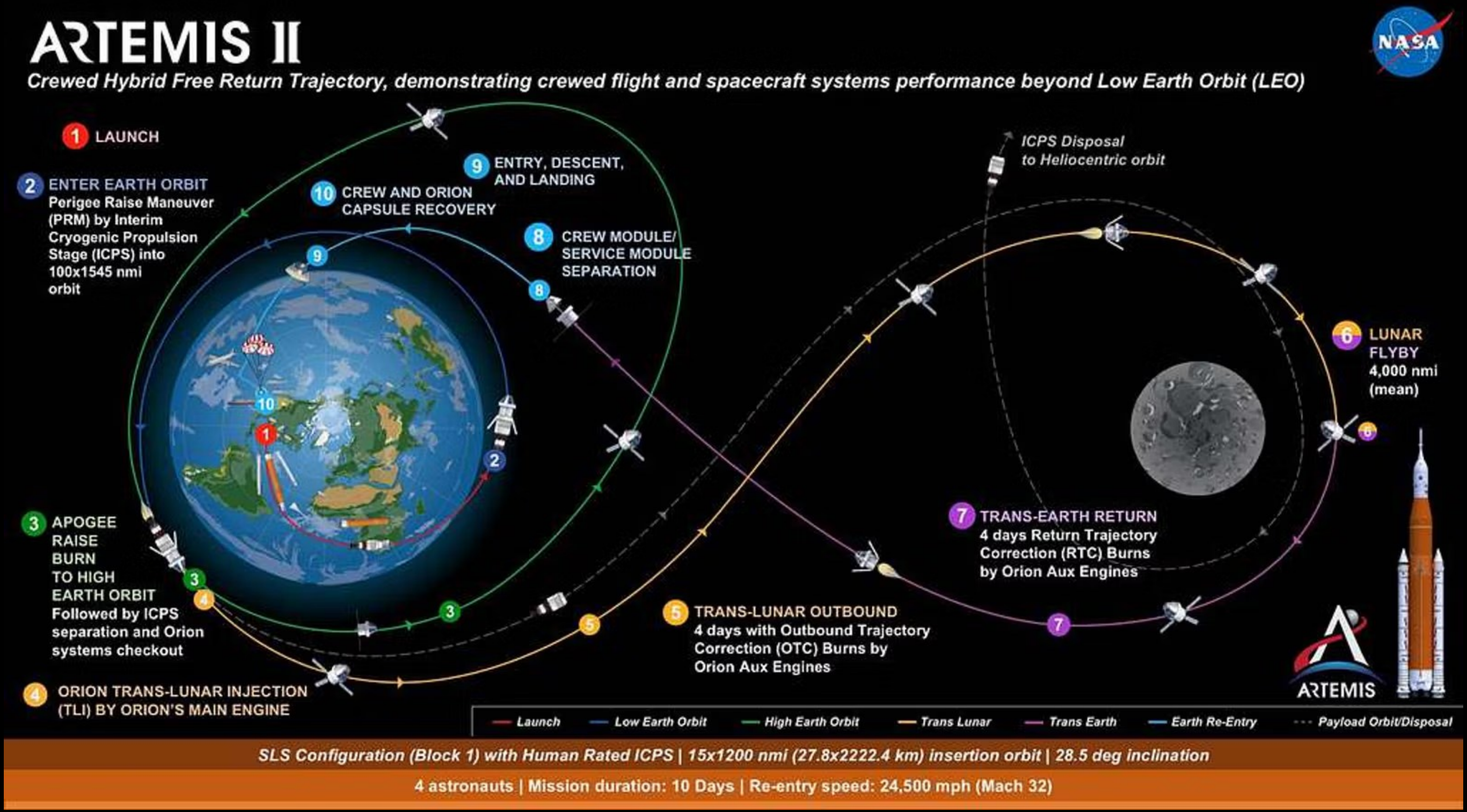

ICPS/Orion Separation
03:24:15
8,529
73,093,408
At Ignition
SRB Separation
LAS Jettison
Core Stage MECO
Core Stage/ICPS Separation
Time (hr:min:sec) 00.00.00 00:02:09 00:03:18 00:08:03 00:08:15
Speed (mph): 0 3,177 4,373 17,661 17,710
Altitude (feet): 0 155,958 285,334 510,891 533,273
ICPS Perigee Raise Maneuver
00:49:49
13,039
7,189,694
ICPS Apogee Raise Burn
01:47:50
17,710
631,789
Start ICPS/Orion Prox Ops Demo
03:24:15
End ICPS/Orion Prox Ops Demo
Orion Perigee Raise Burn
Max Q
Time: 00:01:11
Speed: 1,061 Mph
Altitude: 42,091 ft
Tower Clear & Initiate Roll/Pitch Maneuver
Time: 00:00:09
Speed: 81 Mph
Altitude: 598 ft
Launch
Time: 00:00:00
Speed: 0 Mph
Altitude: 0 ft
SRB Atlantic Splashdown
Time: 00:06:10
Speed: 10,222
Altitude: 405,175
Core Stage Pacific Splashdown
Time: 02:08:23



ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1. **LAUNCH**
   Astronauts lift off from pad 39B at Kennedy Space Center.
2. **JETTISON SOLID ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **APOGEE RAISE BURN TO HIGH EARTH ORBIT**
   Begin 23.5 hour checkout of spacecraft.
6. **ORION SEPARATION FROM INTERIM CRYOGENIC PROPULSION STAGE (ICPS) FOLLOWED BY PROX OPS DEMO**
   Plus manual handling qualities assessment for up to 2 hours.
7. **ORION UPPER STAGE SEPARATION (USS) BURN**
   Begins high Earth orbit checkout. Life support, exercise, and habitation equipment evaluations.
8. **PERIGEE RAISE BURN**
9. **TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
   Lunar free return trajectory initiated with European service module.
10. **OUTBOUND TRANSIT TO MOON**
    Outbound Trajectory Correction (OTC) burns as necessary for Lunar free return trajectory; travel time approximately 4 days.
11. **LUNAR FLYBY**
    6,479 miles / 10,427 km (mean) lunar farside altitude.
12. **TRANS-EARTH RETURN**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
13. **CREW MODULE SEPARATION FROM SERVICE MODULE**
14. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
15. **SPLASHDOWN**
    Ship recovers astronauts and capsule.


ARTEMIS II
Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)
1 LAUNCH
2 ENTER EARTH ORBIT
Perigee Raise Maneuver (PRM) by Interim Cryogenic Propulsion Stage (ICPS) into 100x1545 nmi orbit
3 APOGEE RAISE BURN TO HIGH EARTH ORBIT
Followed by ICPS separation and Orion systems checkout
4 ORION TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE
5 TRANS-LUNAR OUTBOUND
4 days with Outbound Trajectory Correction (OTC) Burns by Orion Aux Engines
6 LUNAR FLYBY
4,000 nmi (mean)
7 TRANS-EARTH RETURN
4 days Return Trajectory Correction (RTC) Burns by Orion Aux Engines
8 CREW MODULE/ SERVICE MODULE SEPARATION
9 ENTRY, DESCENT, AND LANDING
10 CREW AND ORION CAPSULE RECOVERY
ICPS Disposal to Heliocentric orbit
ARTEMIS
Launch
Low Earth Orbit
High Earth Orbit
Trans Lunar
Trans Earth
Earth Re-Entry
Payload Orbit/Disposal
SLS Configuration (Block 1) with Human Rated ICPS | 15x1200 nmi (27.8x2222.4 km) insertion orbit | 28.5 deg inclination
4 astronauts | Mission duration: 10 Days | Re-entry speed: 24,500 mph (Mach 32)

Earthrise. William Anders (Apollo 8).
December 24th 1968

Earthset. Reid Wiseman (Artemis 2).
April 6th 2026

Earthset. Reid Wiseman (Artemis 2).
April 6th 2026.

https://en.wikipedia.org/wiki/Artemis_II#/media/File:Artemis_II_in_Eclipse.jpg

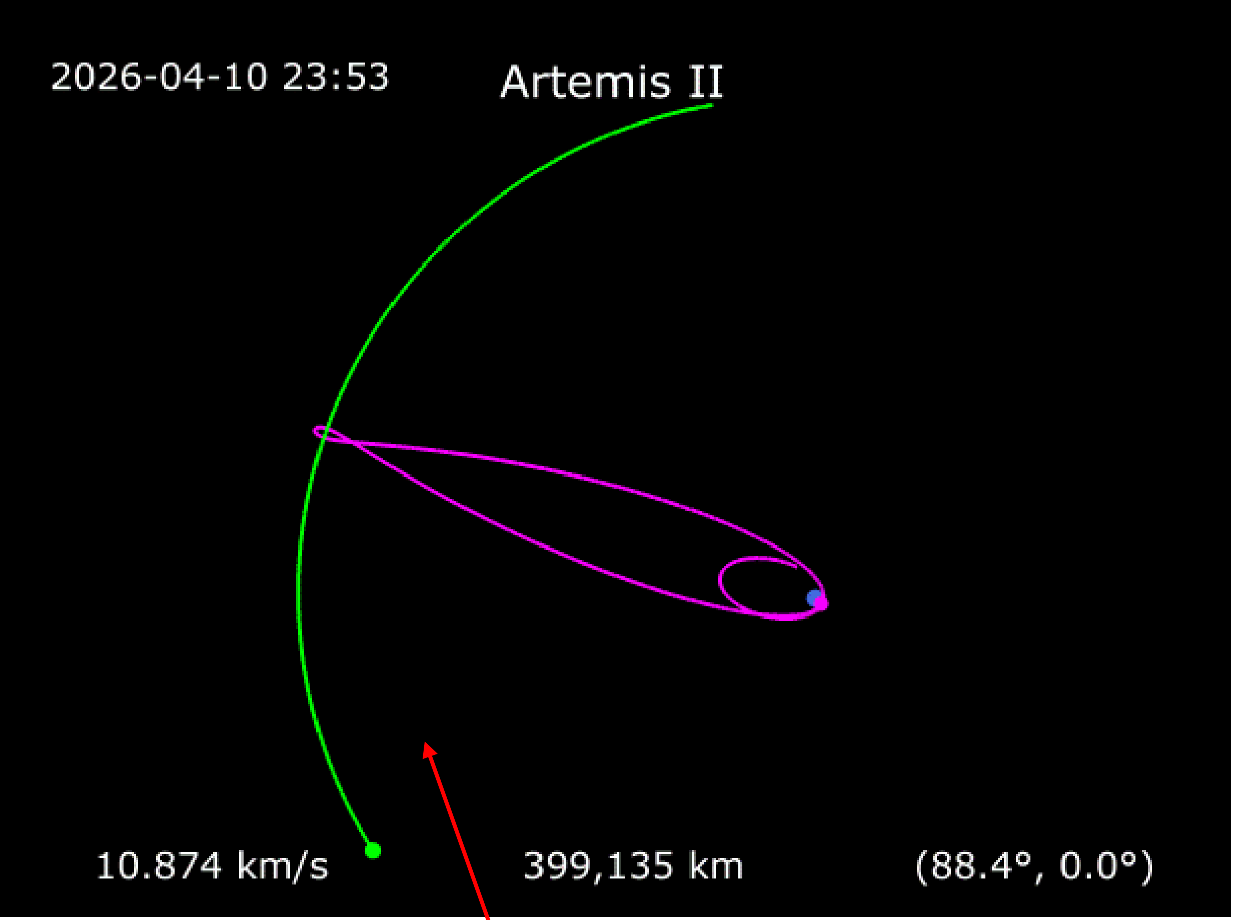
Captured by the Artemis II crew during their lunar flyby on April 6, 2026, this image shows the Moon fully eclipsing the Sun.

54 minutes of totality and extending the view far beyond what is possible from Earth. The corona forms a glowing halo around the dark lunar disk, revealing details of the Sun’s outer atmosphere typically hidden by its brightness.

The faint glow of the nearside of the Moon is visible in this image, having been illuminated by light reflected off the Earth.

Earth facing side

Opposite ‘dark side’ of the Moon

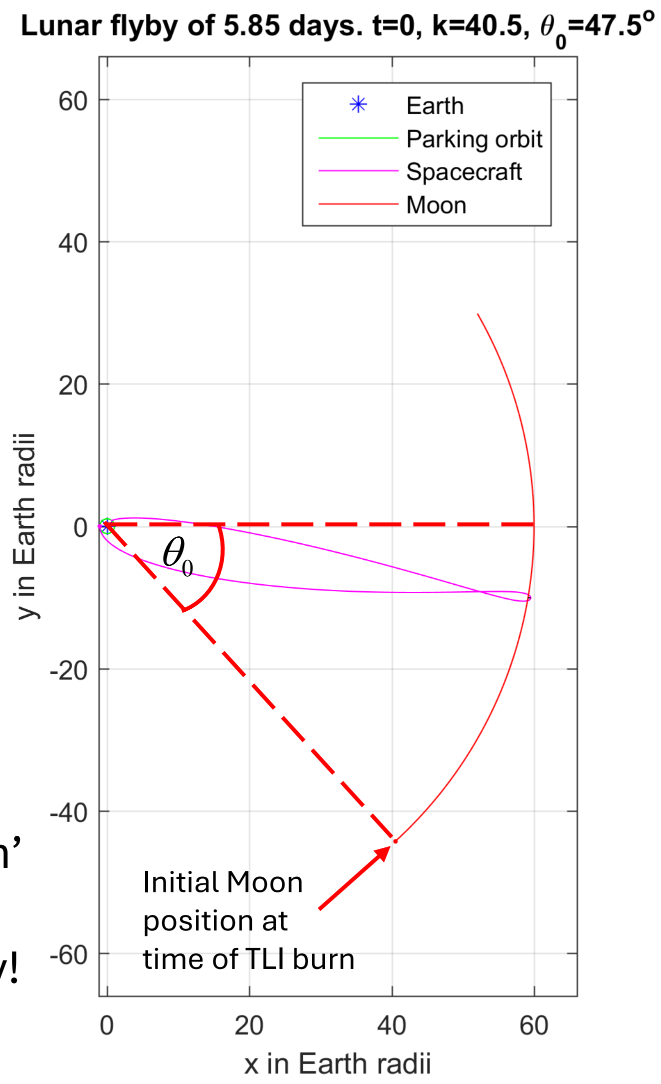


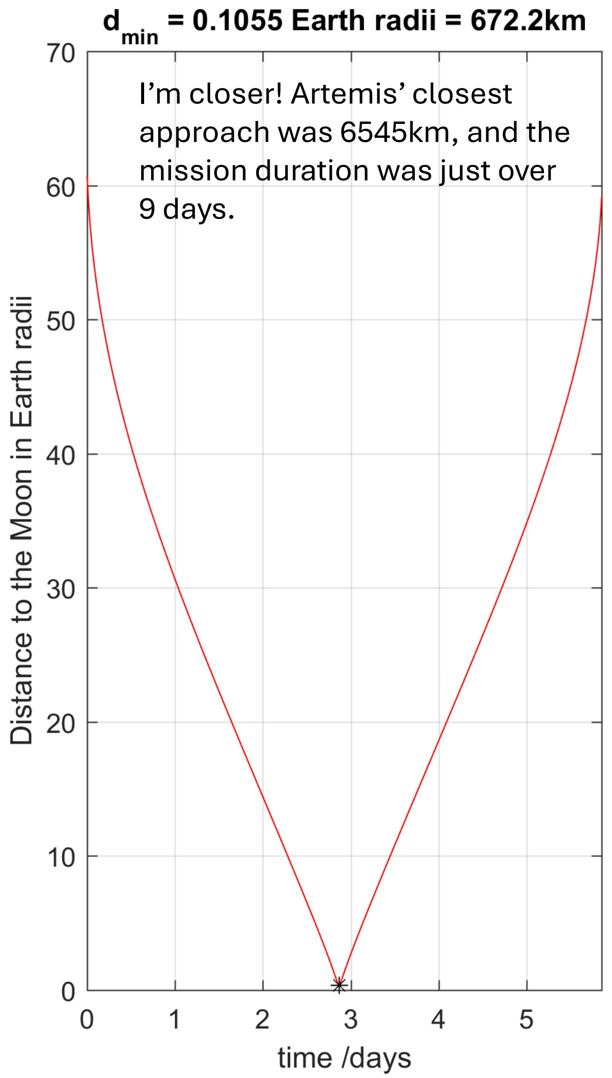
https://en.wikipedia.org/wiki/Artemis_II

- Assume an initial *parking orbit* of 185km above surface of the Earth. Ignore the actual intermediate manoeuvre to a higher elliptical orbit.
- Assume an instantaneous Trans Lunar Injection (TLI) ‘burn’ to increase the parking orbit speed by k %.
- Beyond that, assume no further thrust phases, just gravity!

Approximate simulation of trajectory:

- Circular orbits of Earth about Sun and Moon about Earth
- Orbits are in the same plane
  (actually, the Moon’s orbit is about 5° off the *Plane of the Ecliptic*)





Parking orbit speed

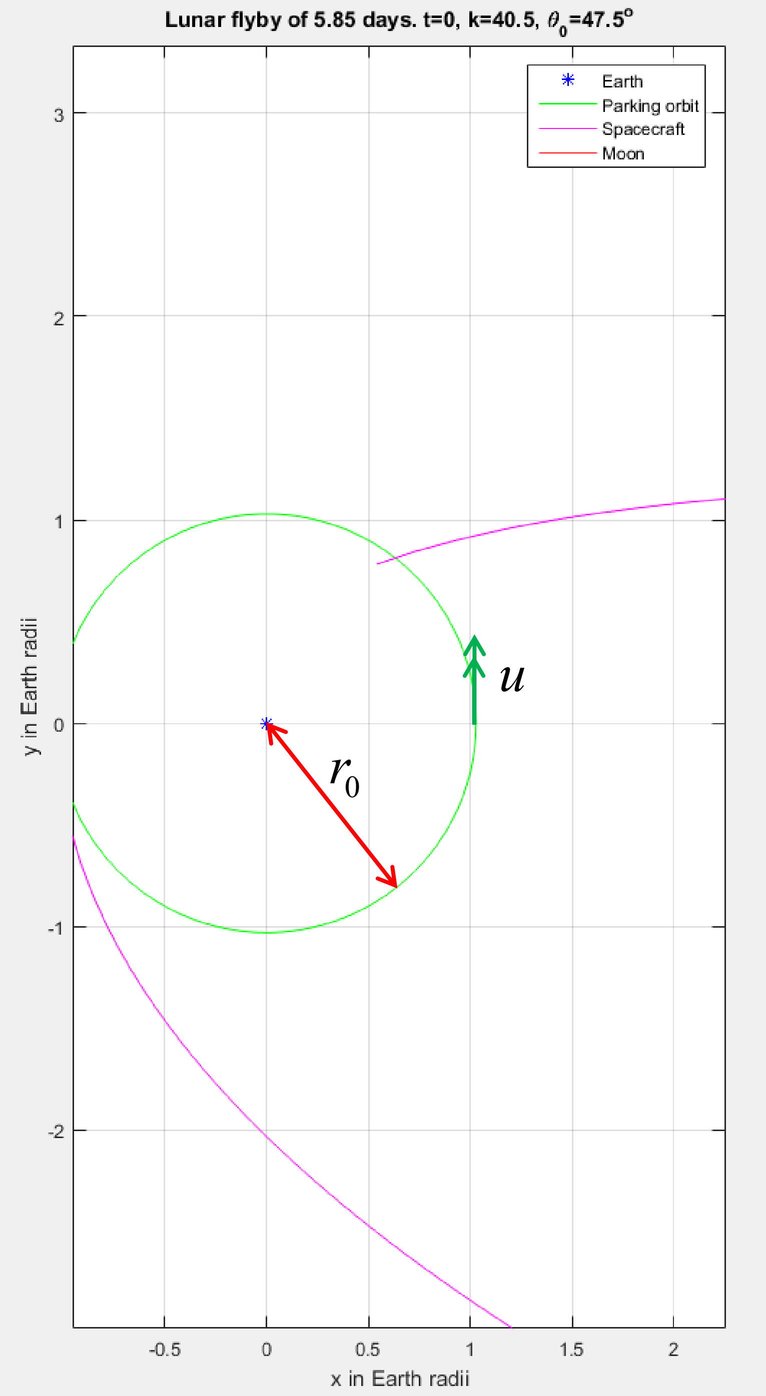
mass x radial acceleration for circular motion

Force of gravity between Earth and spacecraft

$$\frac{mu^2}{r_0} = \frac{GM_\oplus m}{r_0^2}$$

$$\therefore u = \sqrt{\frac{GM_\oplus}{r_0}} \qquad r_0 = 185\,\text{km} + R_\oplus$$

$$\therefore u = 7{,}795\,\text{m/s}$$



$$G = 6.67\times10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}$$

$$M_\oplus = 5.972\times10^{24}\,\text{kg}$$

$$R_\oplus = 6.371\times10^{6}\,\text{m}$$

$$r_{\oplus M} \approx 60R_\oplus$$

$$M_M = 7.348\times10^{22}\,\text{kg}$$

$$R_M = 1.737\times10^{6}\,\text{m}$$

$$M_\odot = 1.989\times10^{30}\,\text{kg}$$

$$\text{AU} = 149{,}597{,}870{,}700\,\text{m} \approx 1.496\times10^{11}\,\text{m}$$

Speed boost k % for elliptical orbit to intersect with lunar orbit

KE, GPE, Total energy

$$\tfrac{1}{2}mv_0^2 - \frac{GMm}{r_0} = -\frac{GMm}{2a}$$

$$\therefore a = \left(\frac{4}{r_0} - \frac{2v_0^2}{GM}\right)^{-1}$$

$$v_0 = \left(1 + \tfrac{1}{100}k\right)u$$

$$u = \sqrt{\frac{GM}{r_0}}$$

Let $2a = r_{\oplus M} + r_0$

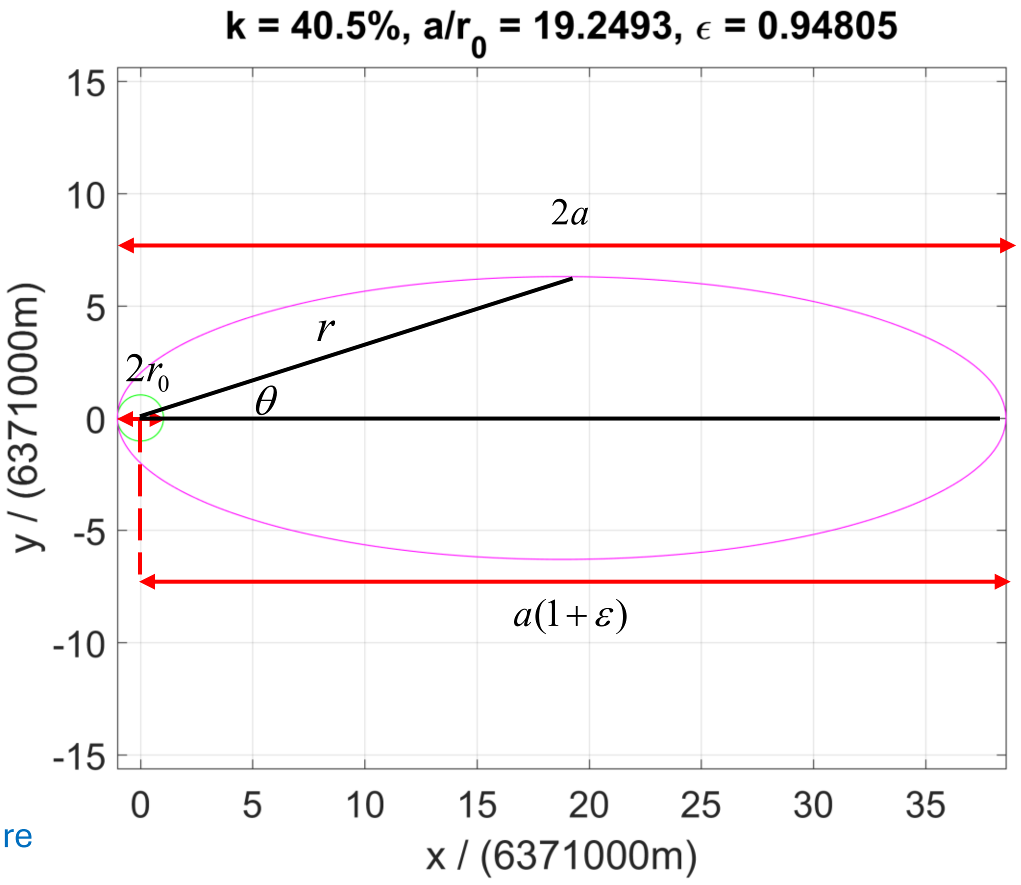
$$k = 100\sqrt{2}\left(1 - \left(\frac{r_{\oplus M}}{r_0} + 1\right)^{-1}\right)^{\frac{1}{2}} - 100$$

$$r_0 = 185\,\text{km} + R_\oplus$$

$$\Rightarrow k = 40.22$$

Integrity had a speed of 10,953 m/s after the TLI burn, so using u = 7,795 m/s for the parking orbit, k = 40.5.

Note in the real mission, the TLI burn followed a prior manoeuvre to a more elliptical Earth orbit to enable system checks prior to TLI. The TLI burn added 867 mph to 23,633mph at the perigee of this orbit.



$G = 6.67\times10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}$ $\quad R_\oplus = 6.371\times10^6\,\text{m}$ $\quad M_\odot = 1.989\times10^{30}\,\text{kg}$ $\quad M_M = 7.348\times10^{22}\,\text{kg}$

$M_\oplus = 5.972\times10^{24}\,\text{kg}$ $\quad r_{\oplus M} \approx 60R_\oplus$ $\quad \text{AU} = 149{,}597{,}870{,}700\,\text{m} \approx 1.496\times10^{11}\,\text{m}$ $\quad R_M = 1.737\times10^6\,\text{m}$

Estimate of initial lunar angle θ_0 (calculate launch time based upon this)

Use Kepler III to determine orbital period of trans-lunar ellipse. Assume half of this corresponds to the time the Moon must orbit to effectively intersect with the *Integrity* spacecraft. We are ignoring the effect of the Moon's gravity (and also the Sun, which will act on the Earth, spacecraft and Moon), but this calculation might be a sensible starting value in an iterative approach.

$$P_M = 2\pi\sqrt{\frac{r_{\oplus M}^3}{GM_\oplus}}$$

$$P = 2\pi\sqrt{\frac{a^3}{GM_\oplus}}$$

$$\therefore \tfrac{1}{2}P = \frac{\theta_0}{2\pi}P_M$$

$$\therefore \theta_0 = \pi\frac{P}{P_M} = \boxed{\pi\left(\frac{a}{r_{\oplus M}}\right)^{\frac{3}{2}}}$$

$$a = \left(\frac{4}{r_0} - \frac{2v_0^2}{GM_\oplus}\right)^{-1}$$

$$v_0 = \left(1 + \tfrac{1}{100}k\right)u$$

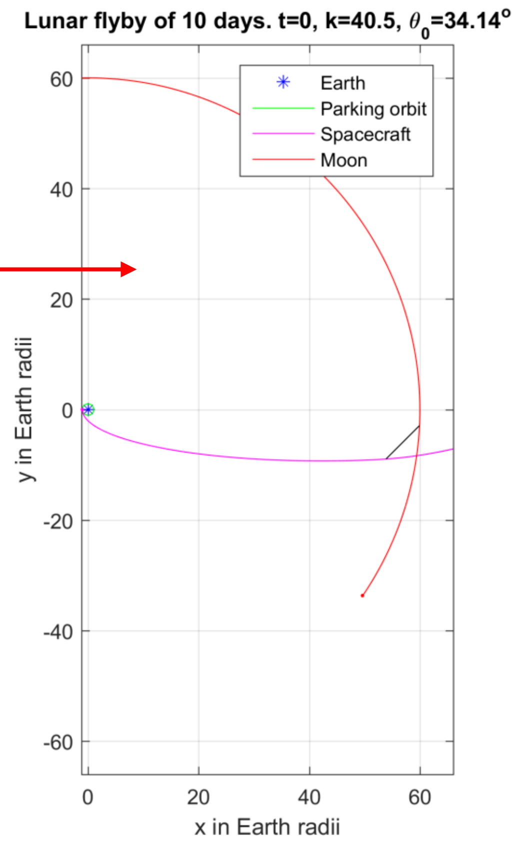
$$u = \sqrt{\frac{GM_\oplus}{r_0}}$$

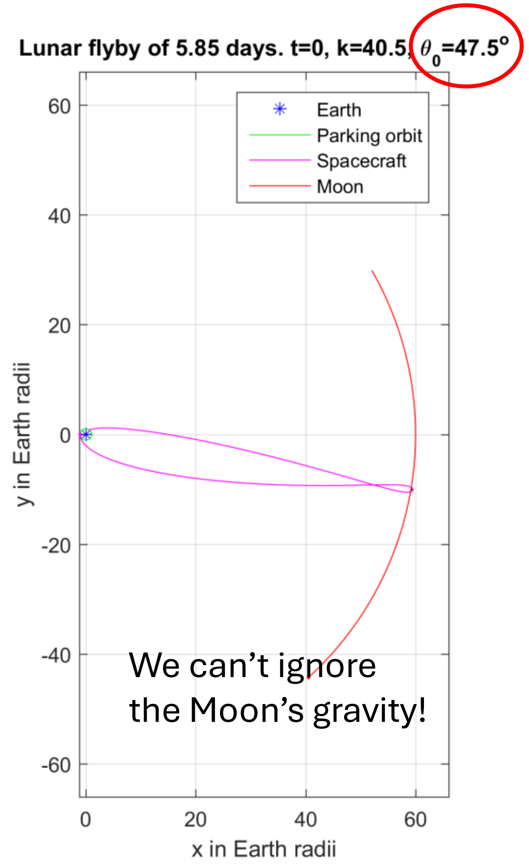
Using: $r_0 = 185\,\text{km} + R_\oplus$

$k = 40.5$

$$\theta_0 = \pi\left(\frac{a}{r_{\oplus M}}\right)^{\frac{3}{2}} \approx \boxed{34.1^\circ}$$

But this is too small!





$G = 6.67\times10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}$ $\quad R_\oplus = 6.371\times10^6\,\text{m}$ $\quad M_\odot = 1.989\times10^{30}\,\text{kg}$ $\quad M_M = 7.348\times10^{22}\,\text{kg}$

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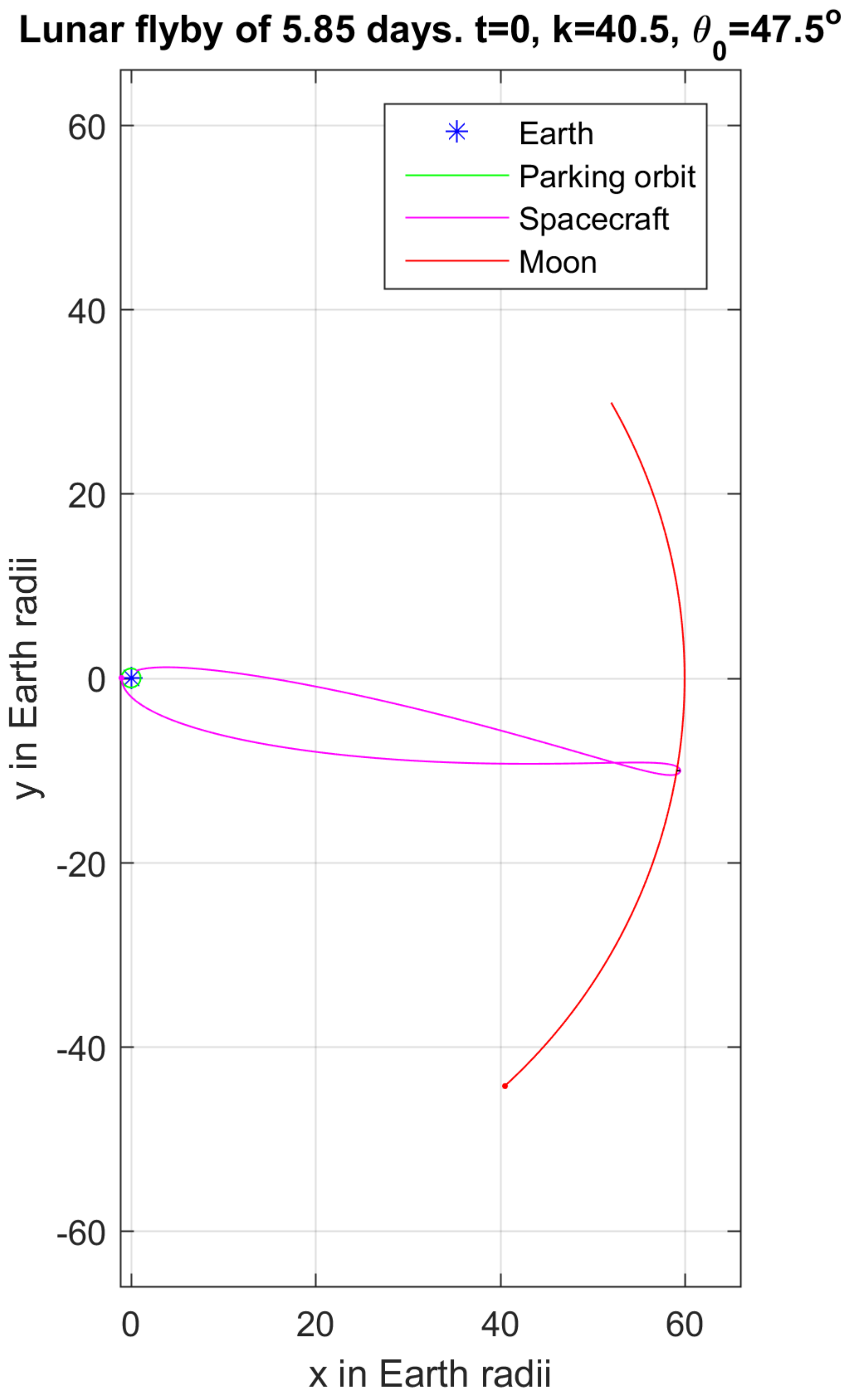
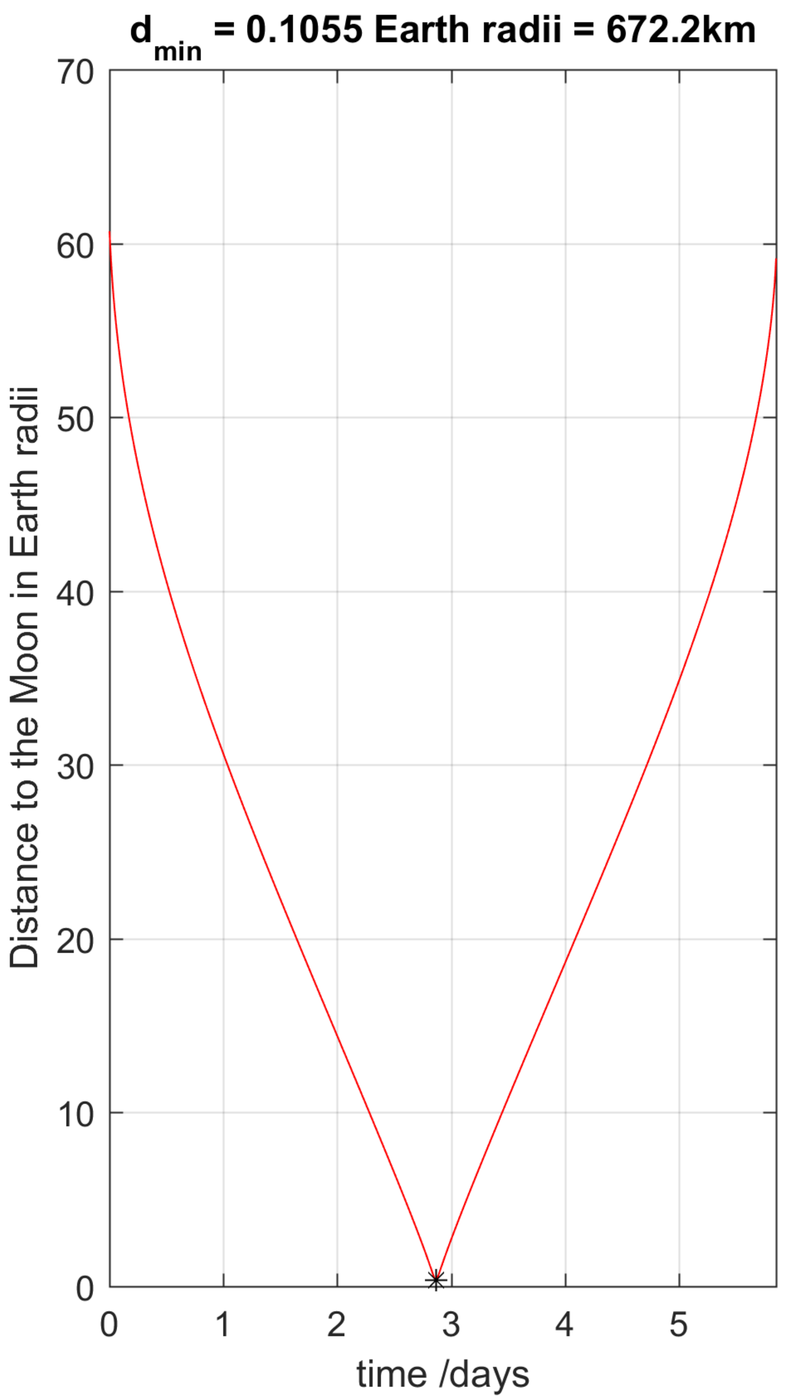
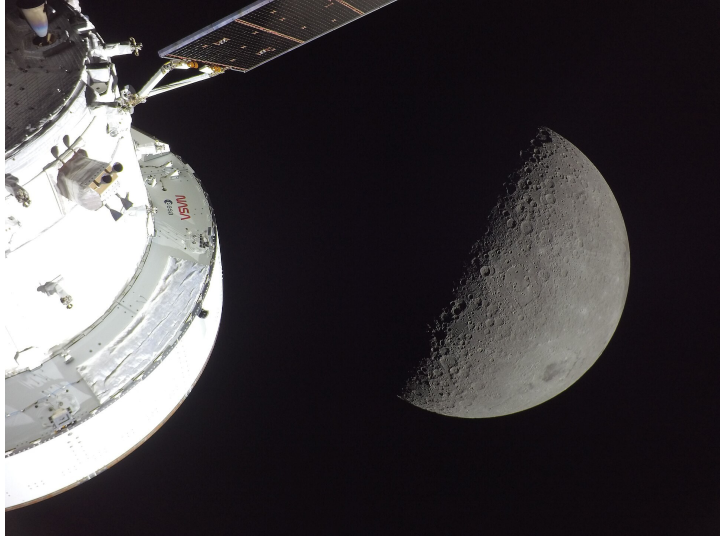






$$G = 6.67\times10^{-11}\ \mathrm{m^3kg^{-1}s^{-2}}$$

$$M_\oplus = 5.972\times10^{24}\ \mathrm{kg}$$

$$R_\oplus = 6.371\times10^{6}\ \mathrm{m}$$

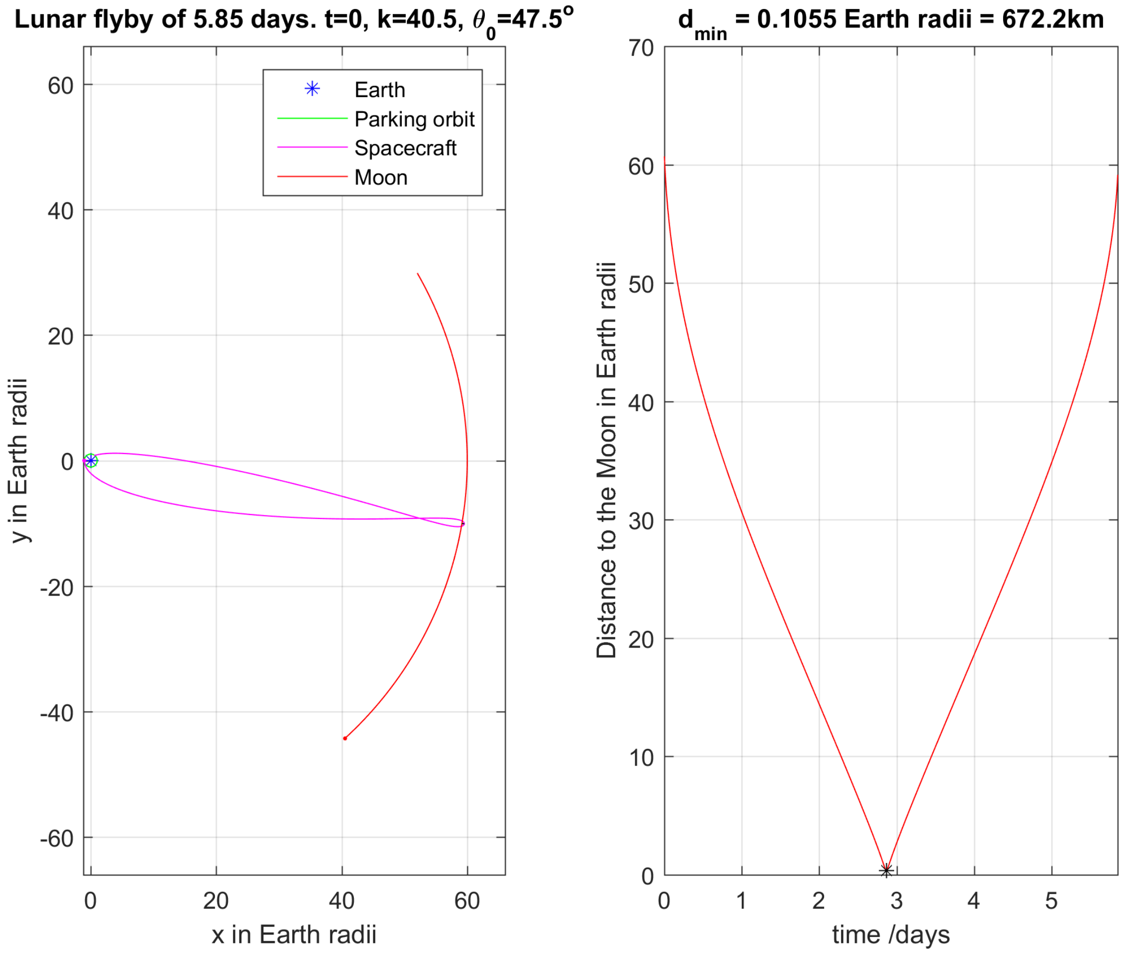
$$r_{\oplus M} \approx 60R_\oplus$$

$$M_M = 7.348\times10^{22}\ \mathrm{kg}$$

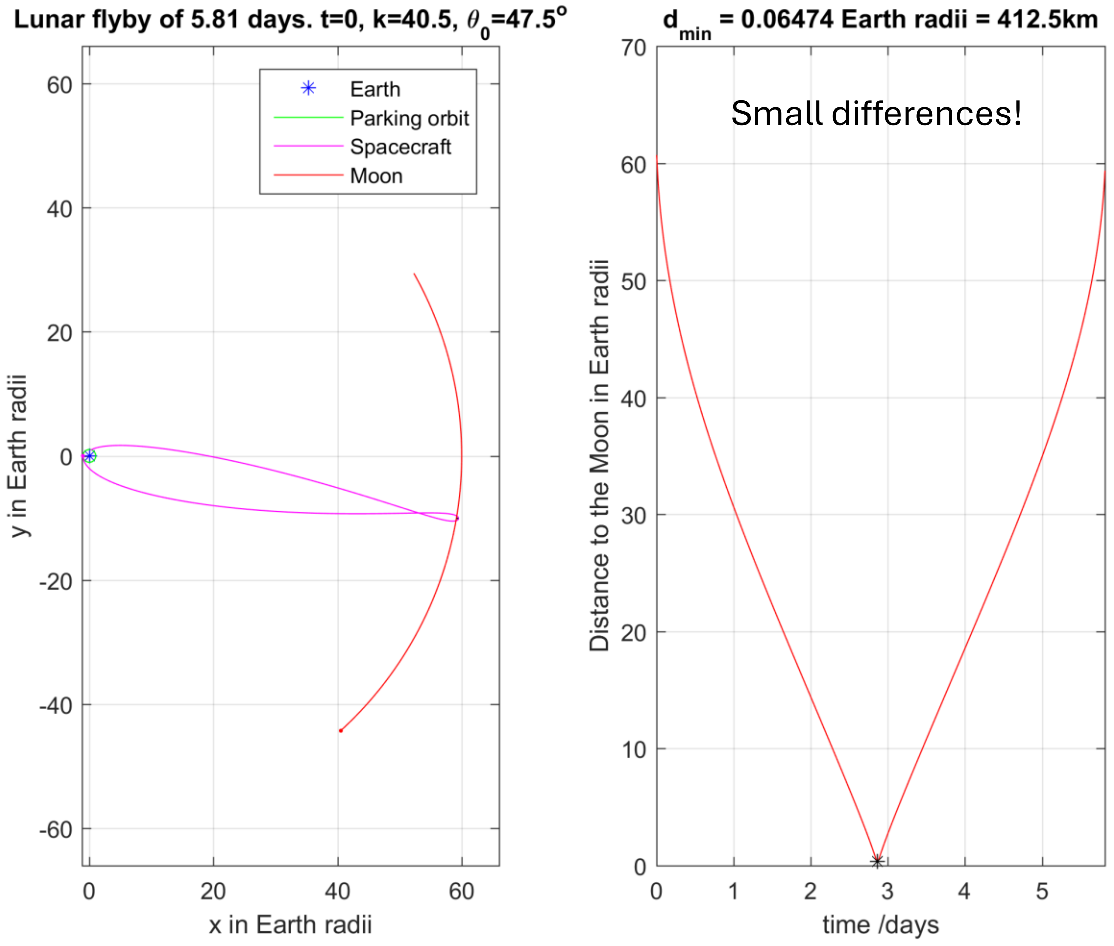
$$R_M = 1.737\times10^{6}\ \mathrm{m}$$

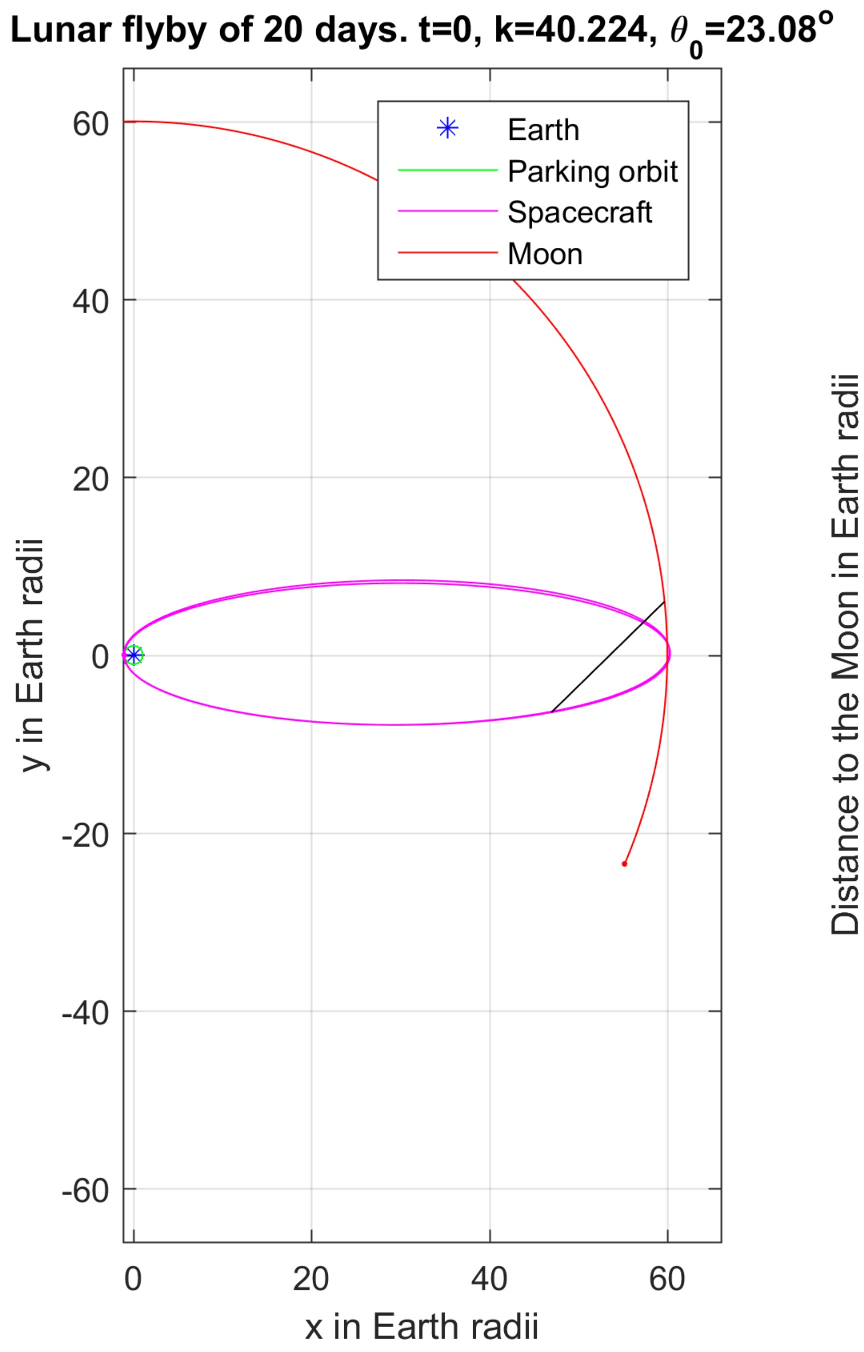
I calculated the orbits using a *Verlet method* (constant acceleration between time steps) and Newtonian gravitation. For calculations I used a Heliocentric coordinate system and computed the orbits or Earth, the Moon and the spacecraft trajectory. I then outputted the results in an Earth-centric frame of reference.

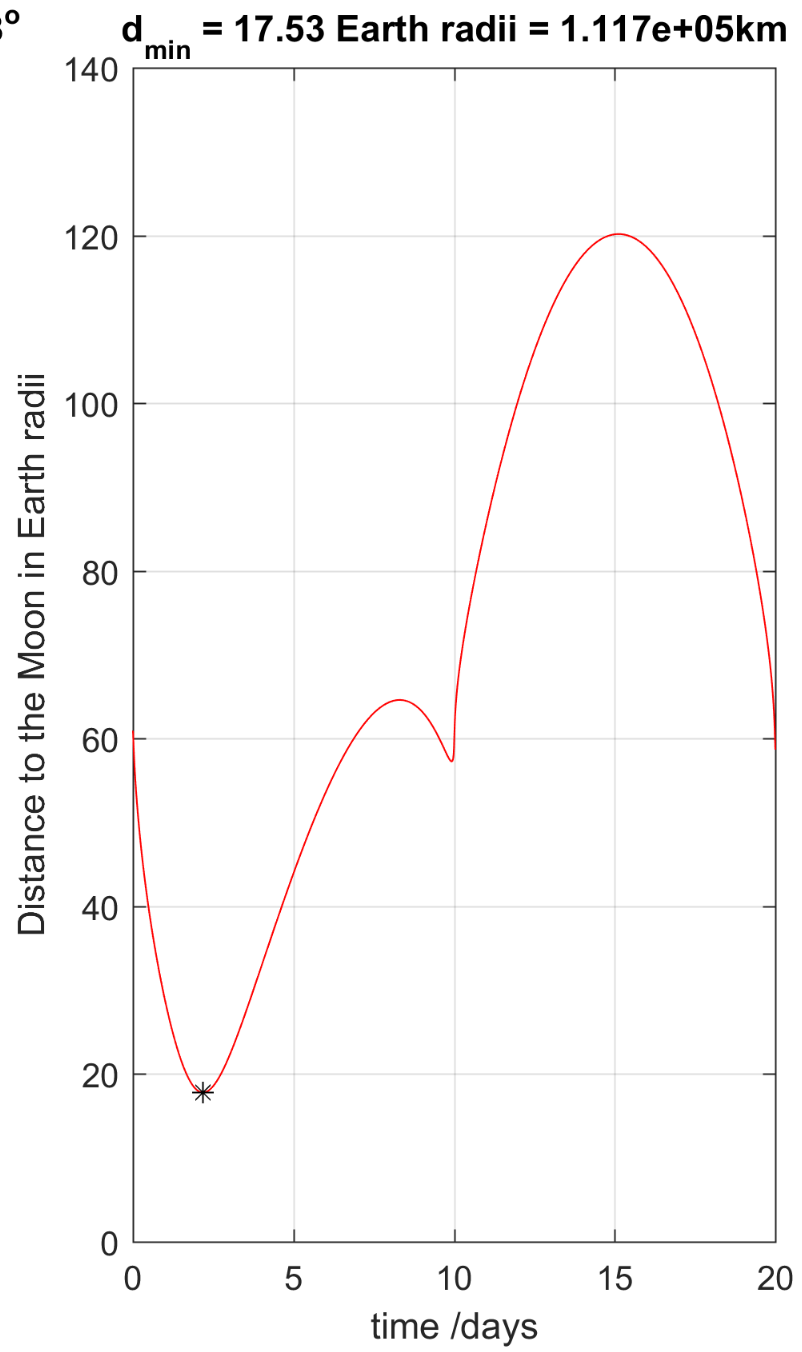
Include effect of the Sun



Don’t include effect of the Sun







See full elliptical TLI orbit if set the mass of the Moon to be zero (!)

I've used:

$$k = 100\sqrt{2}\left(1-\left(\frac{r_{\oplus M}}{r_0}+1\right)^{-1}\right)^{\frac{1}{2}} - 100$$

$$r_0 = 185\,\text{km} + R_\oplus$$

$$\Rightarrow \boxed{k = 40.22}$$

$$a = \left(\frac{4}{r_0} - \frac{2v_0^2}{GM_\oplus}\right)^{-1}$$

$$v_0 = \left(1+\tfrac{1}{100}k\right)u$$

$$u = \sqrt{\frac{GM_\oplus}{r_0}}$$

$$\theta_0 = \pi\left(\frac{a}{r_{\oplus M}}\right)^{\frac{3}{2}} \approx \boxed{23.1^\circ}$$

Verlet method

$$\mathbf{a}_n = f(t_n, \mathbf{r}_n, \mathbf{v}_n)$$

$$t_{n+1} = t_n + \Delta t$$

$$\mathbf{r}_{n+1} = \mathbf{r}_n + \mathbf{v}_n \Delta t + \tfrac{1}{2}\mathbf{a}_n \Delta t^2$$

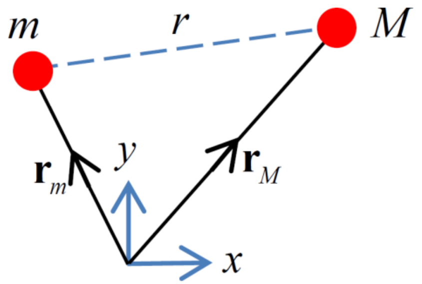
$$\mathbf{V} = \mathbf{v}_n + \mathbf{a}_n \Delta t$$

$$\mathbf{A} = f(t_{n+1}, \mathbf{r}_{n+1}, \mathbf{V})$$

$$\mathbf{v}_{n+1} = \mathbf{v}_n + \tfrac{1}{2}\left(\mathbf{a}_n + \mathbf{A}\right)\Delta t$$

Newton's Law of Gravitation

$$\mathbf{a}_{n,i} = -G\sum_{j \neq i}^{N} M_j \frac{\mathbf{r}_i - \mathbf{r}_j}{\left|\mathbf{r}_i - \mathbf{r}_j\right|^3}$$



$$\mathbf{r} = \mathbf{r}_M - \mathbf{r}_m$$

$$r = |\mathbf{r}|$$

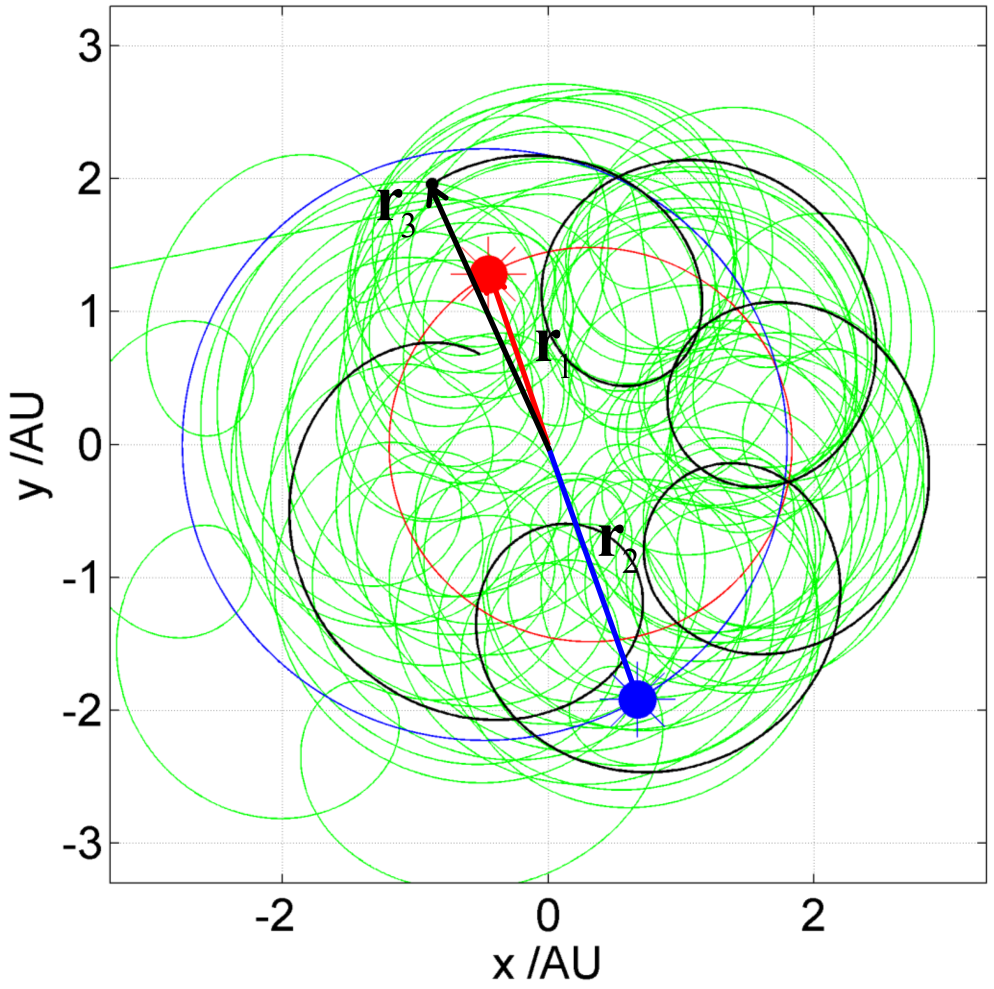
In this simulation:

$$M_1 = 3M_\odot$$

$$M_2 = 2M_\odot$$

$$M_3 \ll M_\odot$$

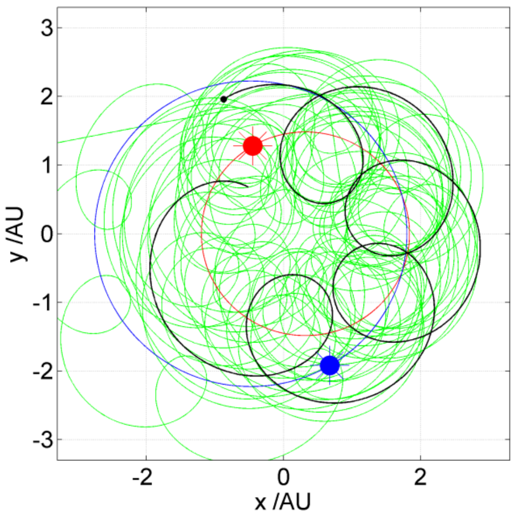
M1=3, M2=2 T=2.32 years, a=3AU, k=1.1, a_p=0.965AU.



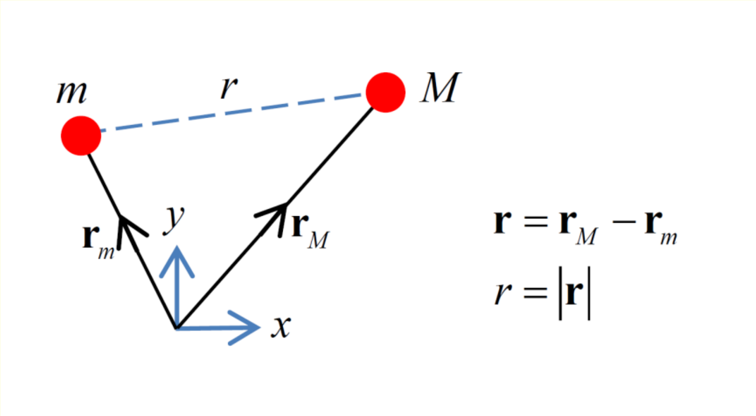
$$\mathbf{a}_n = f(t_n, \mathbf{r}_n, \mathbf{v}_n)$$
$$t_{n+1} = t_n + \Delta t$$
$$\mathbf{r}_{n+1} = \mathbf{r}_n + \mathbf{v}_n \Delta t + \tfrac{1}{2}\mathbf{a}_n \Delta t^2$$
$$\mathbf{V} = \mathbf{v}_n + \mathbf{a}_n \Delta t$$
$$\mathbf{A} = f(t_{n+1}, \mathbf{r}_{n+1}, \mathbf{V})$$
$$\mathbf{v}_{n+1} = \mathbf{v}_n + \tfrac{1}{2}(\mathbf{a}_n + \mathbf{A})\Delta t$$

$$\mathbf{a}_{n,i} = -G\sum_{j \neq i}^{N} M_j \frac{\mathbf{r}_i - \mathbf{r}_j}{\left|\mathbf{r}_i - \mathbf{r}_j\right|^3}$$

M1=3, M2=2 T=2.32 years, a=3AU, k=1.1, a_p=0.965AU.



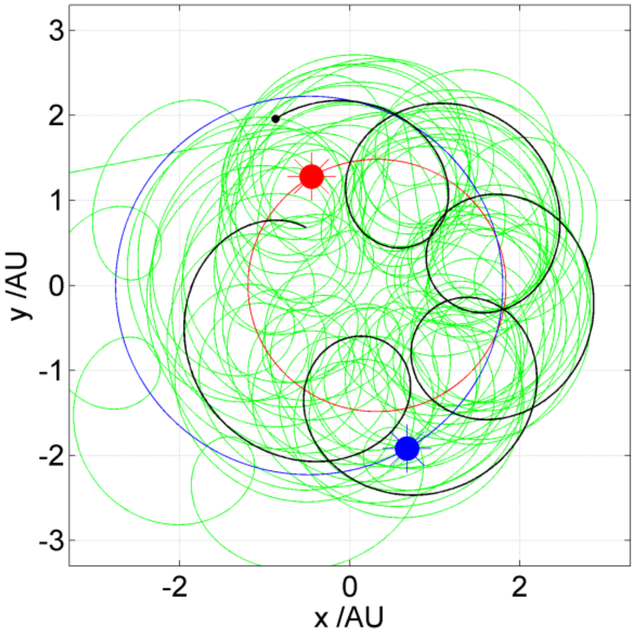

```
function gravity_sim_2_binary_stars_and_planet

%% INPUTS %%

%Semi-major axis of mutual star orbit in AU
a = 3;

%Planet (initial) circular orbit radius about star 1
ap = a/3.11;

%Initial angle from x axis (anticlockwise) of planet /radians
theta0 = pi/4;

%Masses of stars in solar masses
M1 = 3; M2 = 2;

%Initial vy velocity multiplier from mutually circular of stars
k = 1.1;

%Number of orbital periods
num_periods = 50;

%Timestep in years
dt = 0.001;

%Fontsize
fsize = 18;

%Axes limits
limit = 1.1*a;

%Starting period for plot
Pstart = 1.23;
```



$$\mathbf{a}_n = f(t_n, \mathbf{r}_n, \mathbf{v}_n)$$
$$t_{n+1} = t_n + \Delta t$$
$$\mathbf{r}_{n+1} = \mathbf{r}_n + \mathbf{v}_n \Delta t + \tfrac{1}{2}\mathbf{a}_n \Delta t^2$$
$$\mathbf{V} = \mathbf{v}_n + \mathbf{a}_n \Delta t$$
$$\mathbf{A} = f(t_{n+1}, \mathbf{r}_{n+1}, \mathbf{V})$$
$$\mathbf{v}_{n+1} = \mathbf{v}_n + \tfrac{1}{2}(\mathbf{a}_n + \mathbf{A})\Delta t$$

$$\mathbf{a}_{n,i} = -G\sum_{j\neq i}^{N} M_j \frac{\mathbf{r}_i - \mathbf{r}_j}{\left|\mathbf{r}_i - \mathbf{r}_j\right|^3}$$

M1=3, M2=2 T=2.32 years, a=3AU, k=1.1, a_p=0.965AU.



Initial positions

$$X_1(0) = -\frac{M_2 a}{M_1 + M_2}$$
$$Y_1(0) = 0$$
$$X_2(0) = \frac{M_1 a}{M_1 + M_2}$$
$$Y_2(0) = 0$$
$$x(0) = X_1(0) + a_p \cos\theta_0$$
$$y(0) = a_p \sin\theta_0$$

Initial velocities

$$\dot{X}_1(0) = 0$$
$$\dot{Y}_1(0) = \frac{2\pi k X_1(0)}{P}$$
$$\dot{X}_2(0) = 0$$
$$\dot{Y}_2(0) = \frac{2\pi k X_2(0)}{P}$$
$$\dot{x}(0) = -2\pi\sqrt{\frac{M_1}{a_p}}\sin\theta_0$$
$$\dot{y}(0) = -2\pi\sqrt{\frac{M_1}{a_p}}\cos\theta_0 + \dot{Y}_1(0)$$