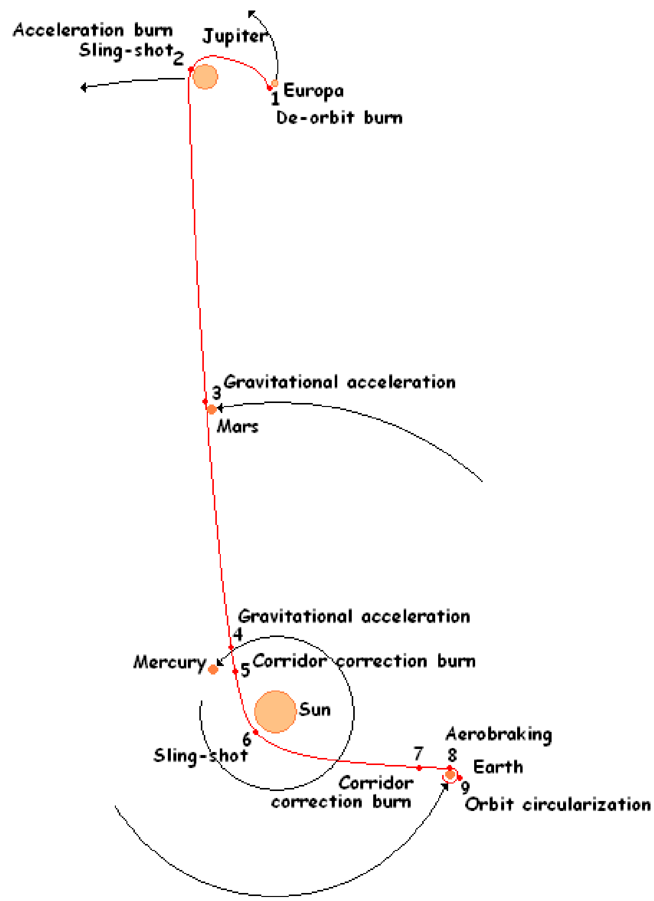
Low-Energy Return from Europa

176 days duration.
4 minutes total engine use time.

Whenever necessary, the radiation shield magnetic field generators should be set to 100%.

Start Orbit5S
Load file "Europa"
Start Orbit5SE
- hot start
- select correct network drive
  (this drive must be active)
- AYSE should be "in position"
- dock with AYSE and turn on all engines



1&2) <u>Departure from Jupiter system</u>

Rather than a direct departure away from Europa, we will perform a de-orbit burn while in Europa orbit to fall towards Jupiter. As the spacecraft approaches its periapsis of 10,000 km it will accelerate. At periapis the speed will be nearly 4 times faster than it was in orbit around Europa. At this point, the engines will be fired prograde to accelerate the spacecraft to 80,000 m/s. This method achieves a the same velocity as a direct departure with less than half the fuel used.

The critical parameters for this manoeuver are:

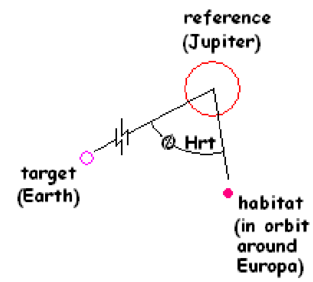
a) maximum speed after periapsis (more = more speed, but smaller direction change)
b) periapsis altitude (lower altitude = more speed and a larger direction change)
c) angle between target, reference, and spacecraft (affects the direction after periapsis)

Since it is hard to manage 3 variables, I will set two of them for you:

a) the maximum speed after periapsis (speed after the engine burn is over): 80,000 m/s

b) the periapsis altitude: 10,000 km

1) **De-orbit burn**
Set: target = Earth
ref = Jupiter
orientation = ccw retro



a) Correct ΘHrt.
The Jupiter sling-shot manoeuver results in about a 270º change in direction, so the ΘHrt that you need is around 90º. The correct must be determined by trial and error. A 0.1º change in angle can produce a difference of millions of kilometres in how close you get to the Earth at the end of the voyage.

Decide on a ΘHrt angle, record it, then try it out, running the process to step 7.

b) De-orbit burn duration.
The TRANSORB software can be used to calculate an approximate change in speed that your de-orbit engine burn must achieve.
Set: target = Jupiter
ref = Jupiter
Read off the distance to target.

TRANSORB Input

current orbit:	5 (Jupiter)
current altitude:	(distance to target read off from the ORBIT5S software)
ending altitude:	10,000 km
engine acceleration:	180 (not critical for this application)

TRANSORB Output

delta-V:	this is the amount by which your orbital speed must change.

The delta-V will be negative, since we are dropping down in altitude. This means that we must slow down in our orbit around Jupiter (while not crashing into Europa, around which we also are in orbit).

Post de-orbit burn speed = ref Vo + delta-V

We must use ref-Vo as our starting speed rather than V hab-ref, since, being in orbit around Europa, our V hab-ref is constantly changing as we go around Europa.

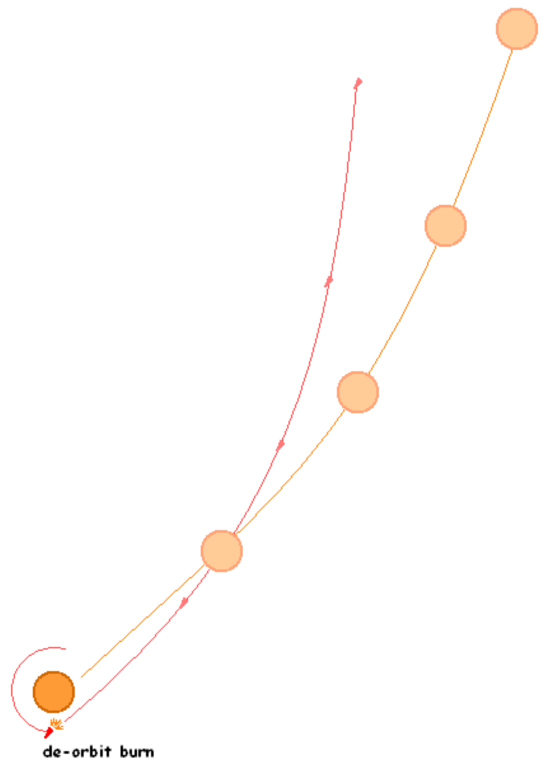
TRANSORB only gives an approximate delta-V. As we start to fall towards Jupiter, Europa will pull ahead of us. While we are still close to it, its gravity will tend to pull us forward, speeding us up and giving us too much speed, which will result in a periapsis above Jupiter that is too high. To compensate for this, you will need to slow down more than the TRANSORB delta-V suggests.

Save you state to a file before the de-orbit burn so that you can easily retry the manoeuver until you get the correct delta-V.

c) Initiate de-orbit burn
Make certain that your orientation is still ccw retro.

Once you have a delta-V that you want to try out, re-select Earth as your target until the spacecraft is at the ΘHrt that you are going to try.

At this moment, select Jupiter as the target so that you can monitor your speed around Jupiter. Immediately select full thrust (you only have a few seconds to start this before you are no longer at the correct ΘHrt)



Unless you are directly between Europa and Jupiter or directly opposite Jupiter, your Vcen will not be zero. This will affect your periapsis speed, altitude, and position.

To compensate for this during you de-orbit burn select manual orientation, rotate slightly to one side or another until Vcen is approximately zero.

When the desired de-orbit speed is reached, shut off the engines.

As soon as the de-orbit burn is complete, Vcen will start to go negative as the spacecraft falls towards Jupiter. This is normal.

Set time acceleration to 0.375
When the spacecraft is a few thousand kilometres from Europa, set time acceleration to 10.000
When the spacecraft is close to Jupiter, set time acceleration to 2.000. Continue to reduce time acceleration as you get closer to periapsis so that: 1) you don't overshoot and, 2) don't alter the periapsis with to overly-large time steps.

d) Judging your de-orbit success
When close enough to Jupiter, press 'o' to project your orbit.
i) If periapsis projection is within 10 km of 10,000 km, continue to coast towards the periapsis.
ii) If periapsis is within 100 km of 10,000 km, you can try to adjust by applying engine thrust towards or away from the planet.
iii) If your periapsis projection is more than 100 km away from 10,000 km, reload your saved state and try another delta-V (slow down more if your projected periapsis is to high, slow down less if it is too low).

2) **Jupiter Sling-shot and Acceleration Burn**

Set: orientation = ccw prog
target = Jupiter
ref = Jupiter

Exactly at periapsis (Vcen = 0) apply full thrust.
When V hab-ref = 80,000 m/s, shut down engines. Try to hit 80,000 m/s to within 10 m/s.

As you climb away from Jupiter, your V hab-ref will decrease. This is because Jupiter's gravity will continually slow you down. This is normal, but it also means that you cannot adjust your V hab-ref if you overshoot or undershoot it. When you get farther from Jupiter and closer to the Sun, the Sun's gravity will start to speed you up again.

Set time acceleration to 0.375
When 1,000,000 km from Jupiter, set time acceleration to 2.000
When 2,000,000 km from Jupiter, set time acceleration to 60.000

Set: target = Sun
ref = Sun
orientation = deprt ref

This orientation will keep the heat/radiation shield between the crew cabin and the Sun for extra protection from solar radiation.

3) **Close Approach to Mars**
No action is required for this.
Mars' gravity will accelerate the spacecraft to a greater speed.

4) **Close Approach to Mercury**
No action is required for this.
Mercury's gravity will bend the trajectory away from the Sun.

5) **Corridor correction Burn**: 56 million km from the Sun

A speed correction burn ***may*** be required to get the spacecraft into the correct corridor around the Sun for the solar sling-shot manoeuver.

Save your state to a file at this point, so that you can go back and try other burn times if needed.

During this manoeuver the spacecraft orientation must be changed. The heat/radiation shield will no longer offer protection from solar radiation (although the spacecraft hull and magnetic shields will still work). For this reason, this engine burn must be as short as possible (10 s usually is long enough) and occur reasonably far from the Sun.

Set: target = Sun
ref = Sun

Speeding up: set orientation to **pro Vtrg** and apply full thrust.
Slowing down: set orientation to **retr Vtrg** and apply full thrust.

If you must change the speed by more than 2000 m/s, go back to step 1 and try a different ΘHrt.
You will know what changes to your speed are needed at this point after you complete step 7.

6) **Sling-shot Around Sun**
Set orientation to **deprt ref** and keep magnetic radiation shield at maximum.
No other action is required or possible at this point.

7) **Course Correction Burn**

Set: target = Earth
ref = Earth

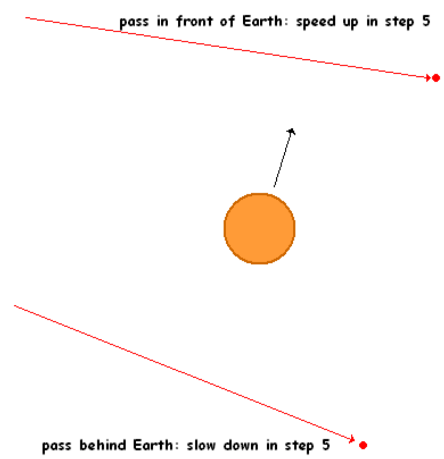
When you are within 500,000 km of earth, press 'o' to project your orbit.

Possible Situations:
a) you never get closer than 5 million km to Earth:
- go back to step 1 and try a different ΘHrt.

b) closer than 5 million km to Earth, but farther than 5000 km:
- go back to step 5 and adjust speed.

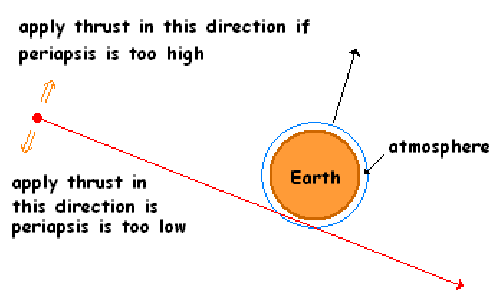
Slow down if you went behind the Earth (you need to give the sun more time to alter your direction).

Speed up if you crossed in front of the Earth (you need to give the sun less time to alter your direction).



c) Your projected periapsis is less than 5000 km:
- use engine thrust perpendicular to your velocity to alter your periapsis.

Set: target = Earth
ref = Earth
orientation = manual



Save your state to a file at this point.

Your goal is to have a periapsis of between 30 and 50 km above the earth.
- If you are too high, you will not slow down enough.
- If you are too low, you will slow down too much, will not be able to enter orbit, and crash.

The exact periapsis altitude depends on your speed. The faster you are going, the lower you need to go to have enough atmosphere to slow you down.

8) **Aerobraking**

Set: target = Earth
ref = Earth
orientation = retr Vtrg
anti gravity = max

retr Vtrg orientation keeps the heat shield forward of the rest of the spacecraft. If any other orientation is used, the spacecraft will burn up.

Do not fire engines while aerobraking as they will be damaged.

Target V hab-ref after aerobraking: between 8000 m/s and 12000 m/s.
If your speed is not within this range, reload you last saved state, go back to step 7, and try a different periapsis.

9) **Circularize Orbit**:
Initiate orbit circularization at an altitude of 300 km.

Set: target = Earth
ref = Earth

a) orient ccw prog (if in a prograde orbit, use ccw retro if in a retrograde orbit).
apply + or - thrust to achieve Vtan = ref Vo

b) orient app targ
apply + or - thrust to achieve Vcen = 0

c) repeat step a) as Vtan will have changed.

10) **Undock from AYSE drive and Land**
Follow procedure from OCESS procedures manual.