Europa Initiative team meeting
Optimisation of the Europan orbits for JEM

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irap astrophysique & planétologie

with the help of :
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1. Interplanetary cruise
    - Tranfers using swing-by's
    - Direct transfer to Jupiter
2. From JOI to EOI
3. Delivery & Relay phase
    - Purpose of those orbits
    - Frozen orbits
    - Halo orbits
4. Science Orbit
    - Connecting halo orbits to science orbits
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Tranfers using swing-by's

Launch Date	Flyby Path	TOF to JOI (yrs.)	C_3 (km^2/s^2)
25 Mar 2020	VEE	6.03	15.6
27 May 2021	VEE	6.87	14.5
21 Nov 2021	**VEE**	**6.37**	**15.0**
15 May 2022	EVEE	7.22	10.2
23 May 2023	VEE	6.18	16.4
03 Sep 2024	VEE	6.71	13.8
01 Aug 2026	VEE	6.94	10.0
21 Jul 2026	VEE	6.15	15.2

Figure 1: Short list of interplanetary trajectories (from ES 2012 Report by NASA

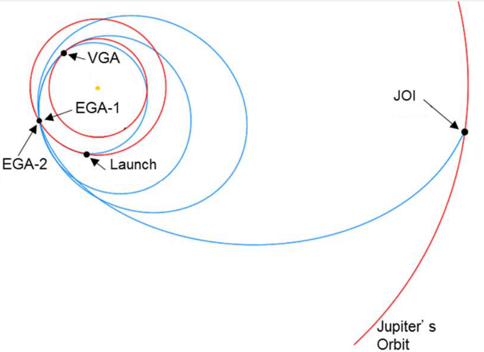

Figure 2: Example of VEEGA trajectory

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Direct transfer to Jupiter

Hohmann transfer :
$\Delta V_1 = 8.80 km/s$
$\Delta V_2 = 5.64 km/s$
TOF $= 2.73$ years

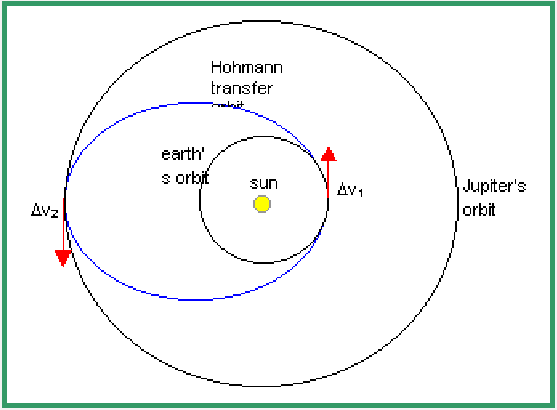

Figure 3: Hohmann transfer

Jovian tour

Table B.2.6-4. Trade-offs between Flight-time, deterministic ΔV, and TID (Si behind 100 mil Al, spherical shell) for various types of tours as compared to the concept baseline tour

JOI-to-EOI, inclusive			
Flight Time (delta yrs)	ΔV (delta km/s)	TID (delta Mrad)	Type of Tour
0	> 5.5	~0	No tour, direct insertion to Europa Orbit from interplanetary trajectory
0.25	4	~0	Callisto gravity assists and v-infinity leveraging
0.5	3	~0	Further Callisto gravity assists and v-infinity leveraging
1	2.5	0.1–0.5	Callisto and Ganymede gravity assists (no endgame)
1.5	1.5	0.8–1.2	Callisto, Ganymede, and Europa gravity assists (4:3, 6:5 endgame)
2.5	1.3	1.7	Callisto, Ganymede, Europa and Io gravity assists

Figure 4: Trade-offs between Flight-time, ΔV, and TID (from ES 2012 Report by NASA)

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Landing site

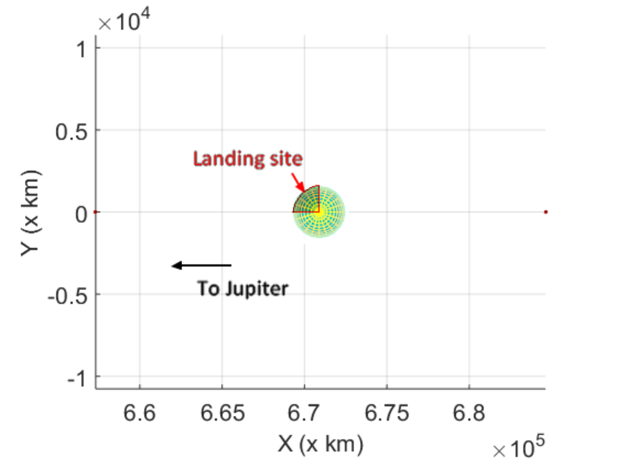

Figure 5: Restricted area for landing site in Jupiter-Europa rotating frame (Projection on Europa Orbital plane)

Delivery : The carrier spacecraft must be within line of sight of the lander stack from deployment to landing in order to provided communications coverage for critical events associated with landing.
Relay : ensure communication with lander around 60% of time

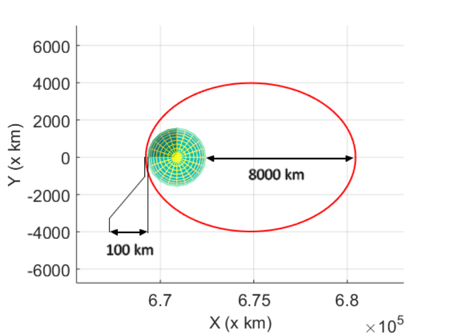

Figure 6: Classc keplerian orbit

Pb : Periastre is circulating around Europa (explain how)

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Frozen orbits

fixed periaspe
low-inclined and stable : expensive to go on a near-polar orbit
R.Russell is investigating them

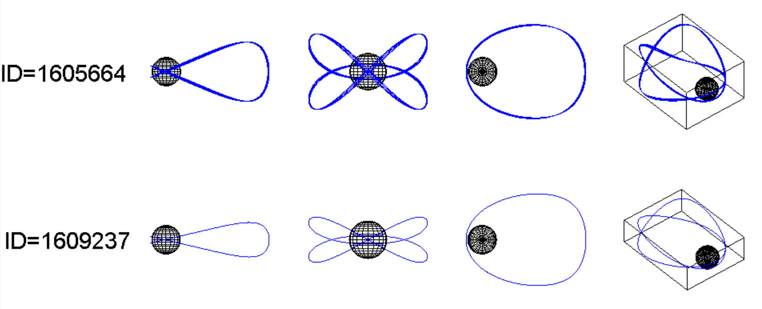

Figure 7: Stable orbits around Europa in the rotating frame (Ryan P. Russell)

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Halo orbits

- Unstable periodic orbits around L1 & L2
- Symmetric about XZ-plane
- Two families : Northern & Southern
- Easy to leave
- Little maneuvers (few m/s for delivery and relay phase) required to stay on orbit
- Maneuvers computed from Earth

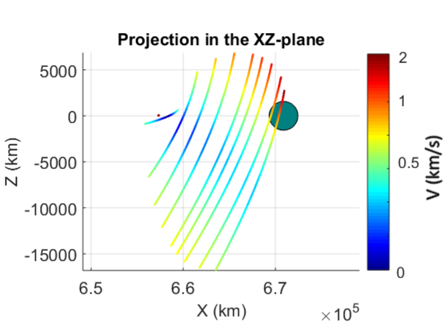

Figure 8: JEL1 Halo orbits

Example of halo orbit

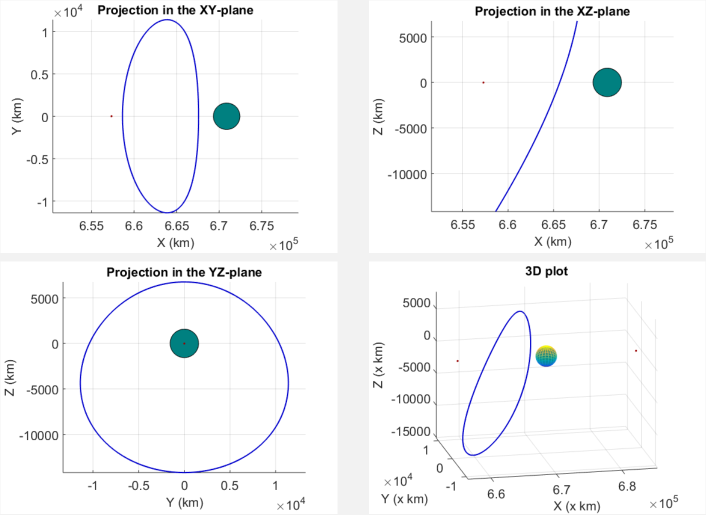

Figure 9: Projection and 3D-view of a JEL1 halo orbit (C = 3.0013) in the rotating frame

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Connecting halo orbits to science orbits

	Min.	Max.
altitude (km)	100	200
inclination (deg)	80	90
duration (days)	30	∞

Table 1: Science orbit characteristics

Description of the algorithm :

- Choose a halo orbit
- Choose a location on halo orbit
- Tangent burn or small burn in the unstable direction
- Search for extrema location
- Second burn to circularize around Europa
- Compute circular orbit until crash on Europa

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Example of transfers ($C_{halo} = 3.0013$)

ΔV_1 (m/s)	ΔV_2 (m/s)	ΔV_{tot} (m/s)	TOF (days)	altitude (km)	inclination (°)
8.0	487.5	495.5	1.31-30.0	190	83.8
216	449.6	665.6	0.51	109.7	86.1
48	480.7	528.7	0.93	146.5	80.9
40	481.4	521.4	1.34	186.9	88.3

Table 2: Transfers with a tangent burn

ΔV_1 (m/s)	ΔV_2 (m/s)	ΔV_{tot} (m/s)	TOF (days)	altitude (km)	inclination (°)
0.8	490.1	490.9	2.27	194.1	80.5
0.5	502.9	503.3	2.91	127.5	82.1
2.8	489.4	492.1	1.83	198.3	80.6
5.6	492.4	497.9	1.64	181.7	80.3

Table 3: Transfers with small burn in the unstable direction

Example of transfers ($C_{halo} = 3.0013$)

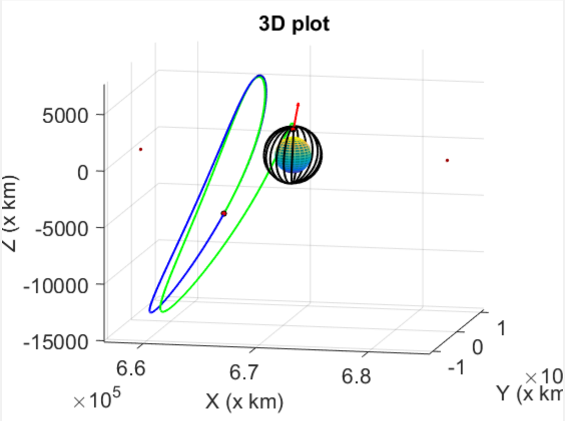

Figure 10: Transfer from a JEL2 Halo orbit (C = 3.0013) to a science orbit (ΔV_{tot} = 495.5m/s, TOF = 1.31d, alt=190km, inc = 83.8°)