A simple, robust and adaptable strategy for ballistic landings on small binary bodies.

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An increased interest for binary asteroids

Discovery mission proposal BASiX

P.I. Dr Daniel Scheeres

ESA Cosmic Vision Marco Polo R.

P.I. Dr A. Barucci & Dr P. Michel

We need **robust ways** for delivering **unpowered landers** to the **surface of asteroids**, while ensuring the **safety of the mothership**.

Summary of the Presentation

SYSTEM DESCRIPTION
- Jacobi integral
- 0-Velocity surfaces
- e.g. 1999 KW4

STRATEGY DESIGN

FEASIBILITY OF STRATEGY
- Periapses maps
- R.T.O.
- Manifold deliveries

LANDING FROM L2
- Linearizing
- Conley criterion
- Release margins

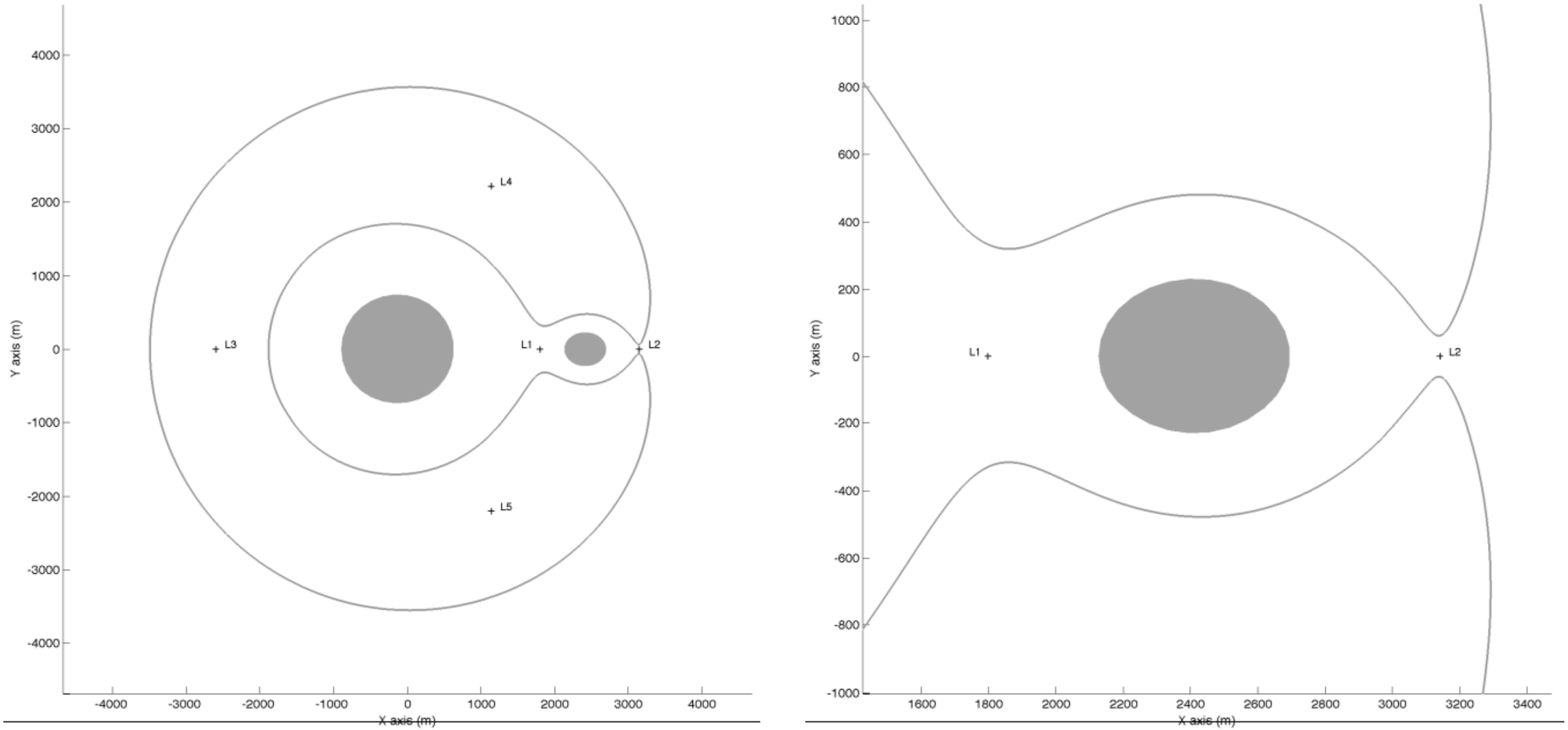
GROUNDING THE LANDER

The exemple: 1999 KW4

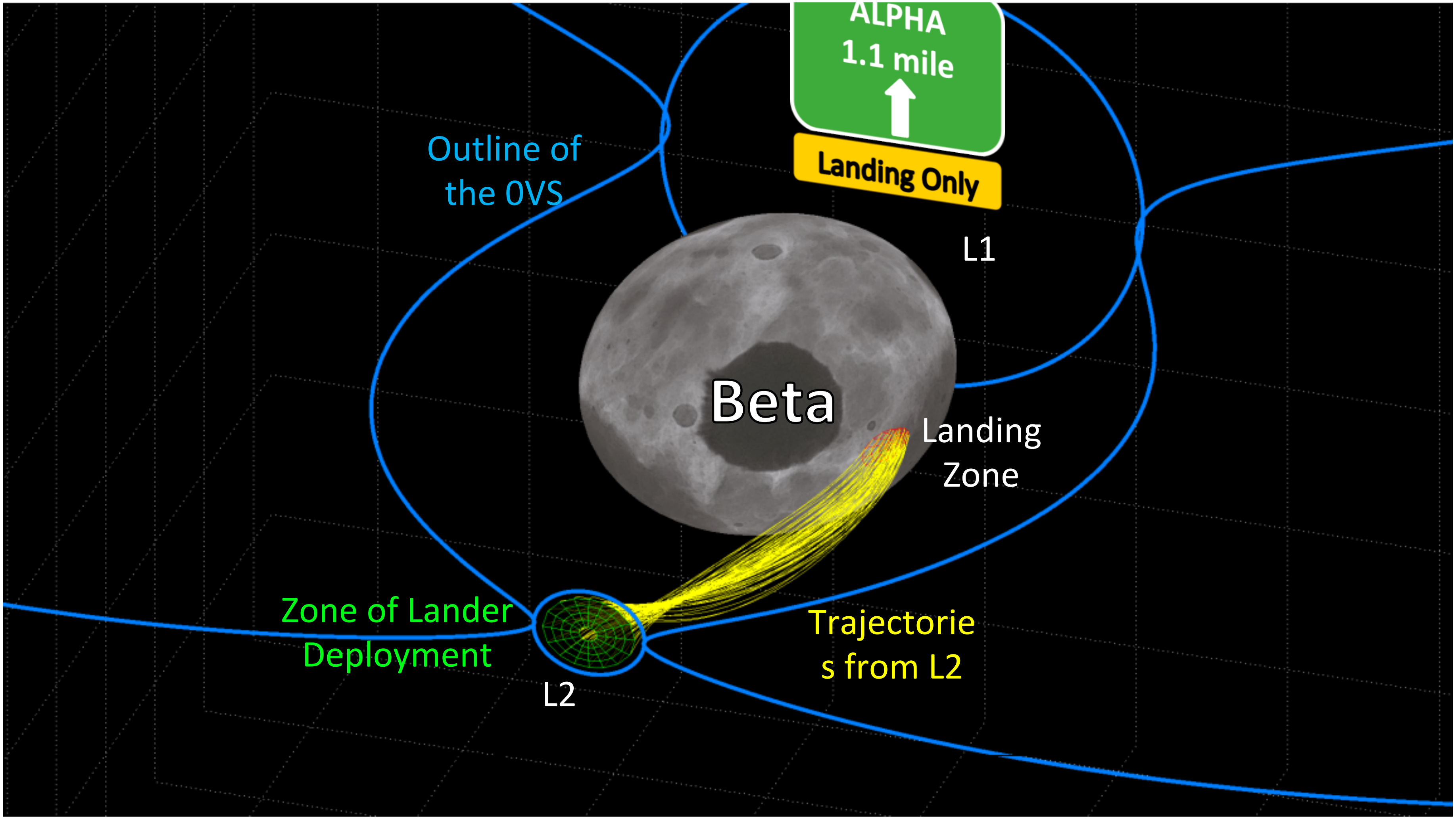
- Binary asteroid system:
  - Alpha (1.5km)
  - Beta (500m prolate) tidally-locked with Alpha
  - Mutual orbit parameters:
    - a = 2.5km
    - e = 0
- Extensively studied
- Representative of binaries (and very similar to 1996 FG3)

Zero-Velocity Surfaces

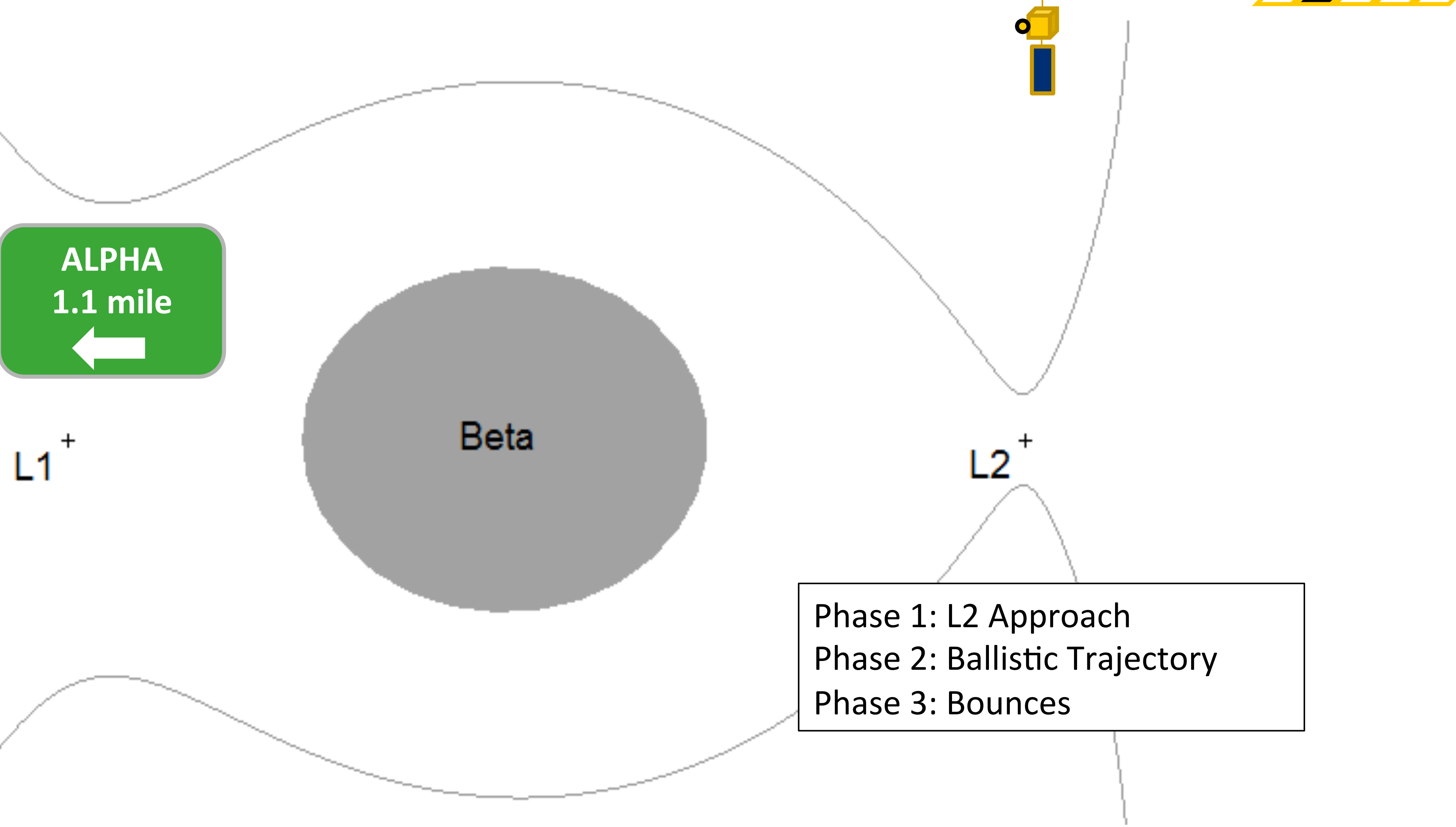
The ZVS separate accessible and forbidden zone of state space



A typical trajectory bundle



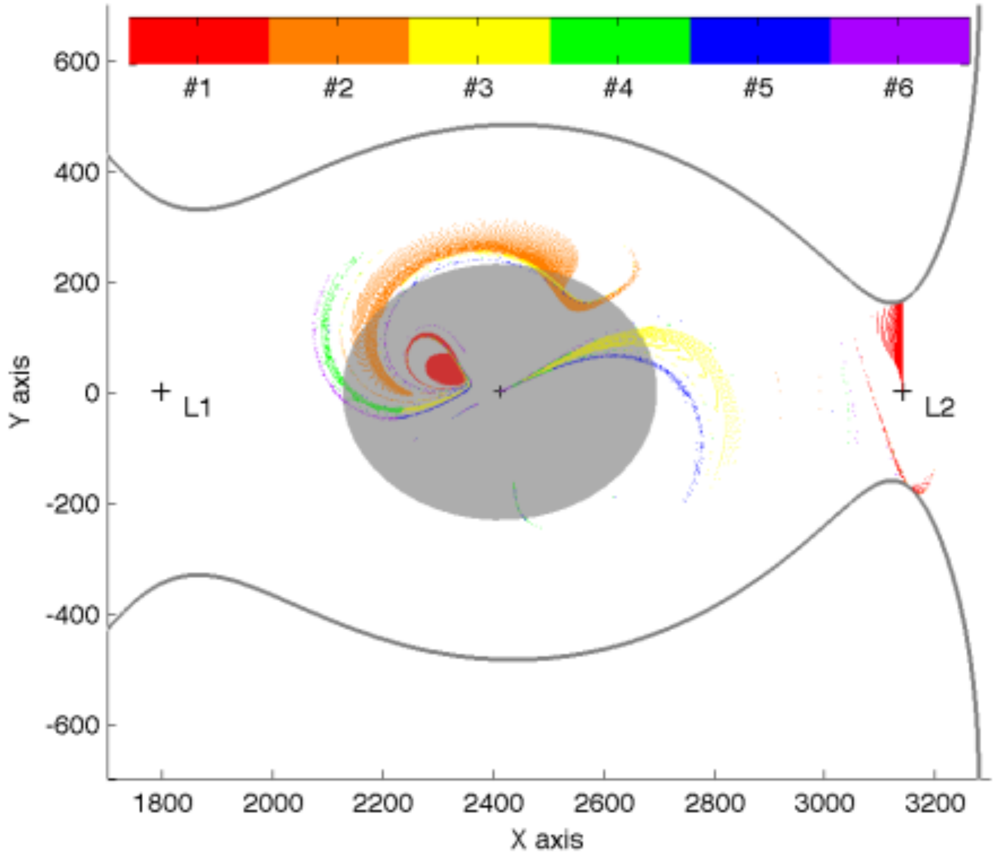
Our landing strategy



Phase 1: L2 Approach
Phase 2: Ballistic Trajectory
Phase 3: Bounces

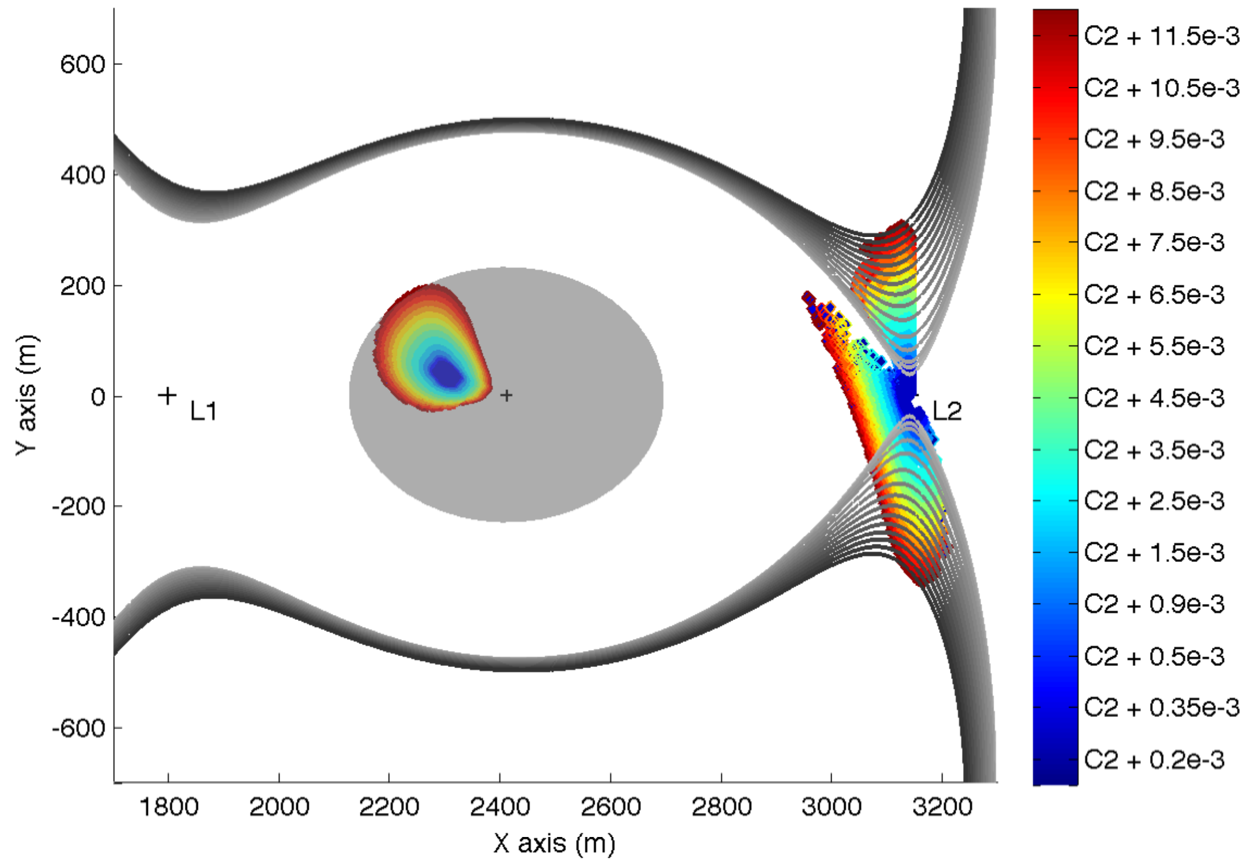
Introducing periapses Poincaré maps

An acceptable landing trajectory is defined as
a trajectory whose **1st periapsis** lies under the asteroid surface.



The shape of the first periapsis region

The 1st periapsis region grows with energy

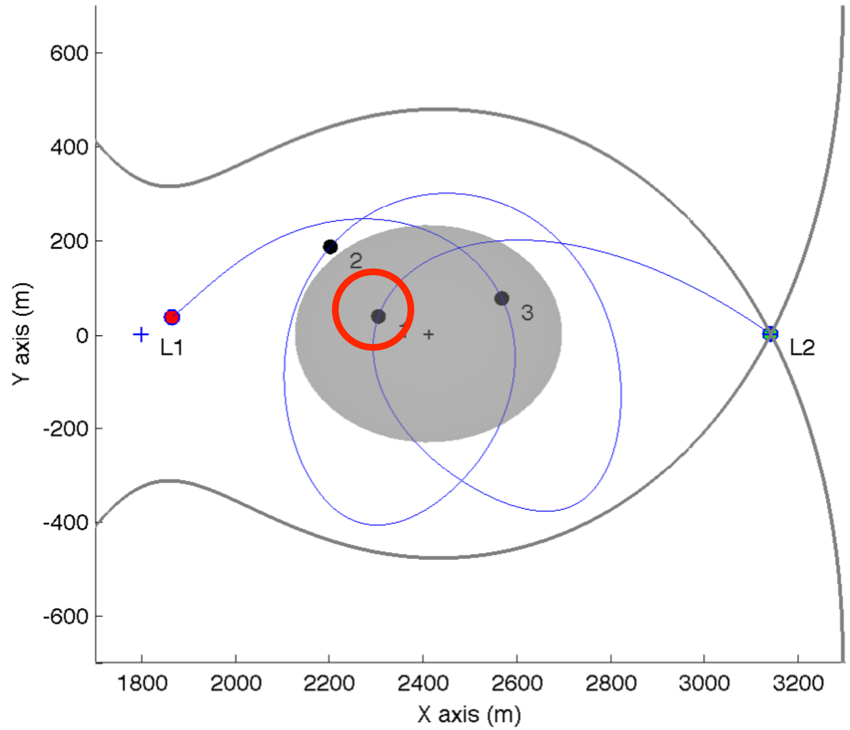


Manifold deliveries and RTO

- Problem has too many variables:
  - Mass fraction μ
  - Energy C
  - Shape and size of the asteroid

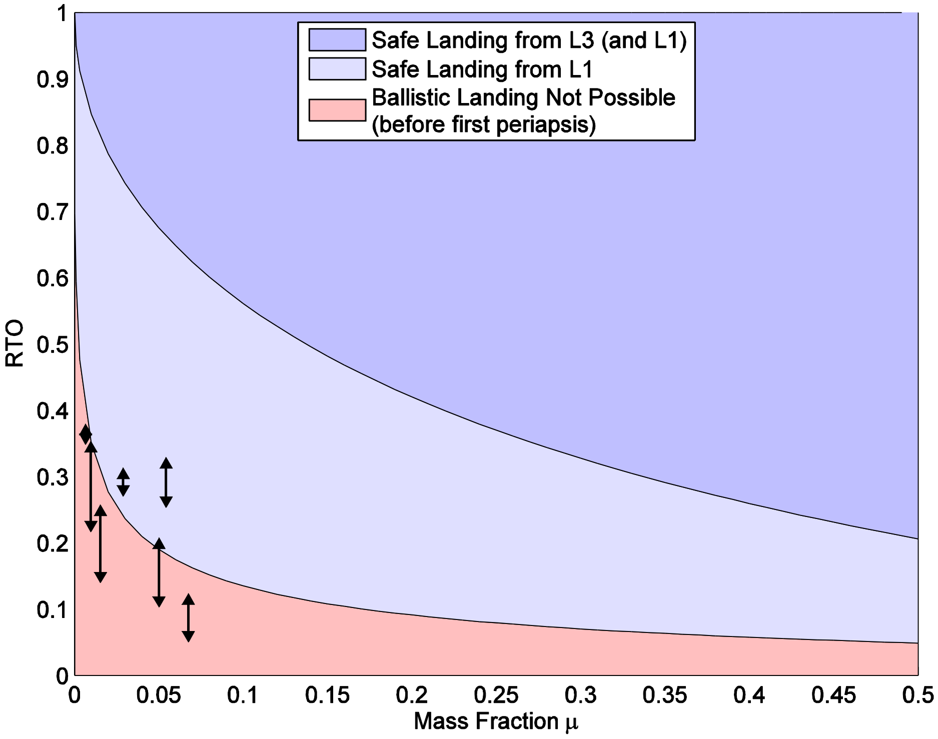
- RTO : Radius-To-Orbit ratio is the radius in normalized units (e.g. , 6.9% for 1999 KW4)

- Manifold delivery reduces to two variables: μ and *RTO*.
  - If 1st periapsis<RTO then **OK** for some range of C
  - If 1st periapsis>RTO then **dangerous** for any range of C

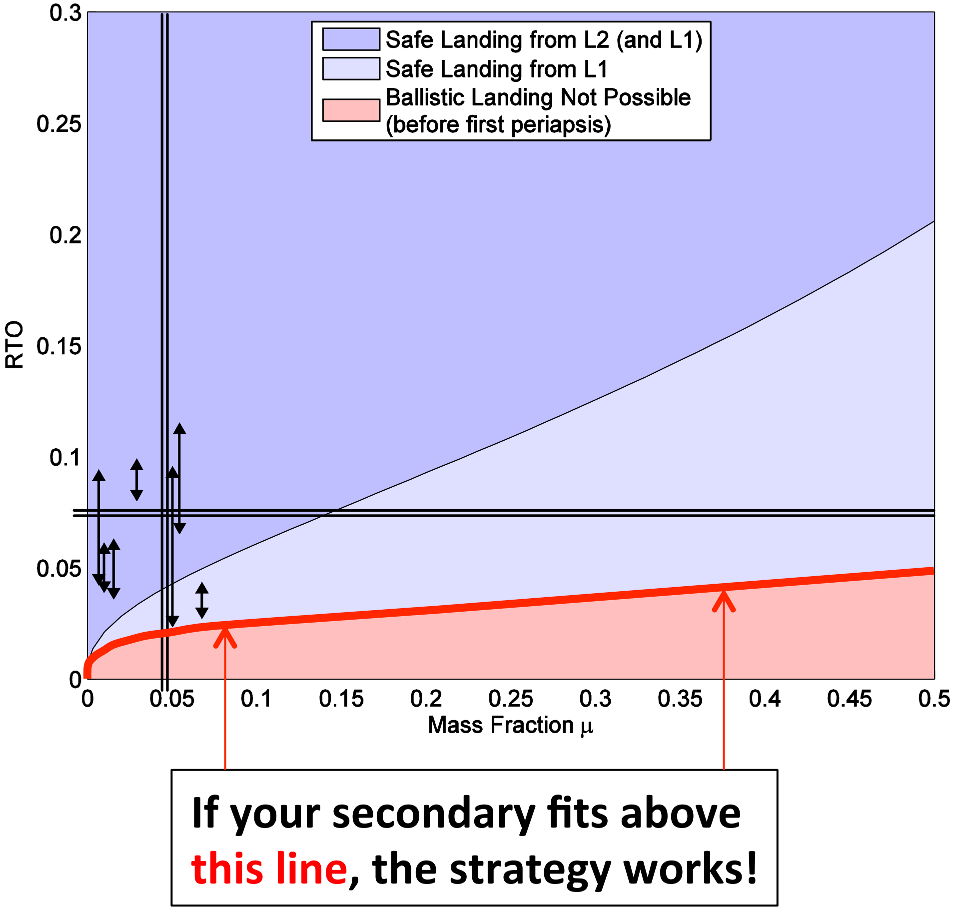


Feasibility of the strategy

Landing on the primary (Alpha)



Landing on the secondary (Beta)



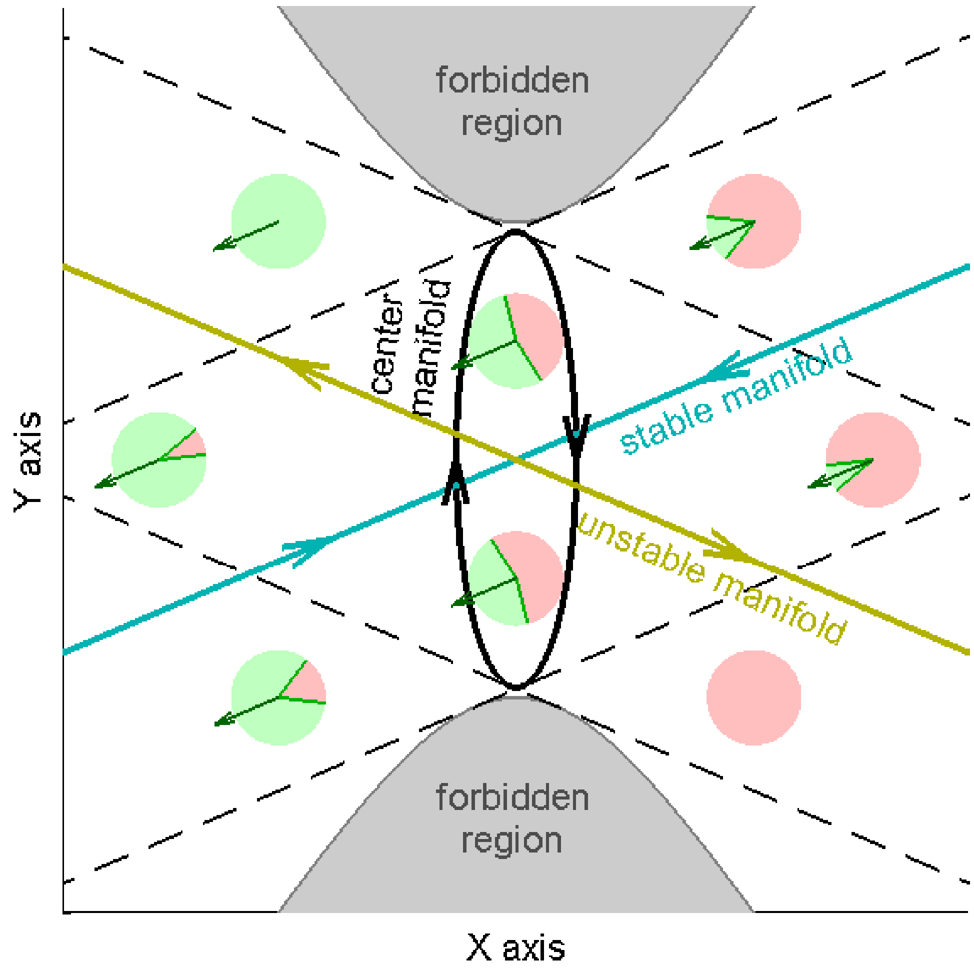
Aiming at the asteroid

All trajectories that enter the secondary's region will impact…

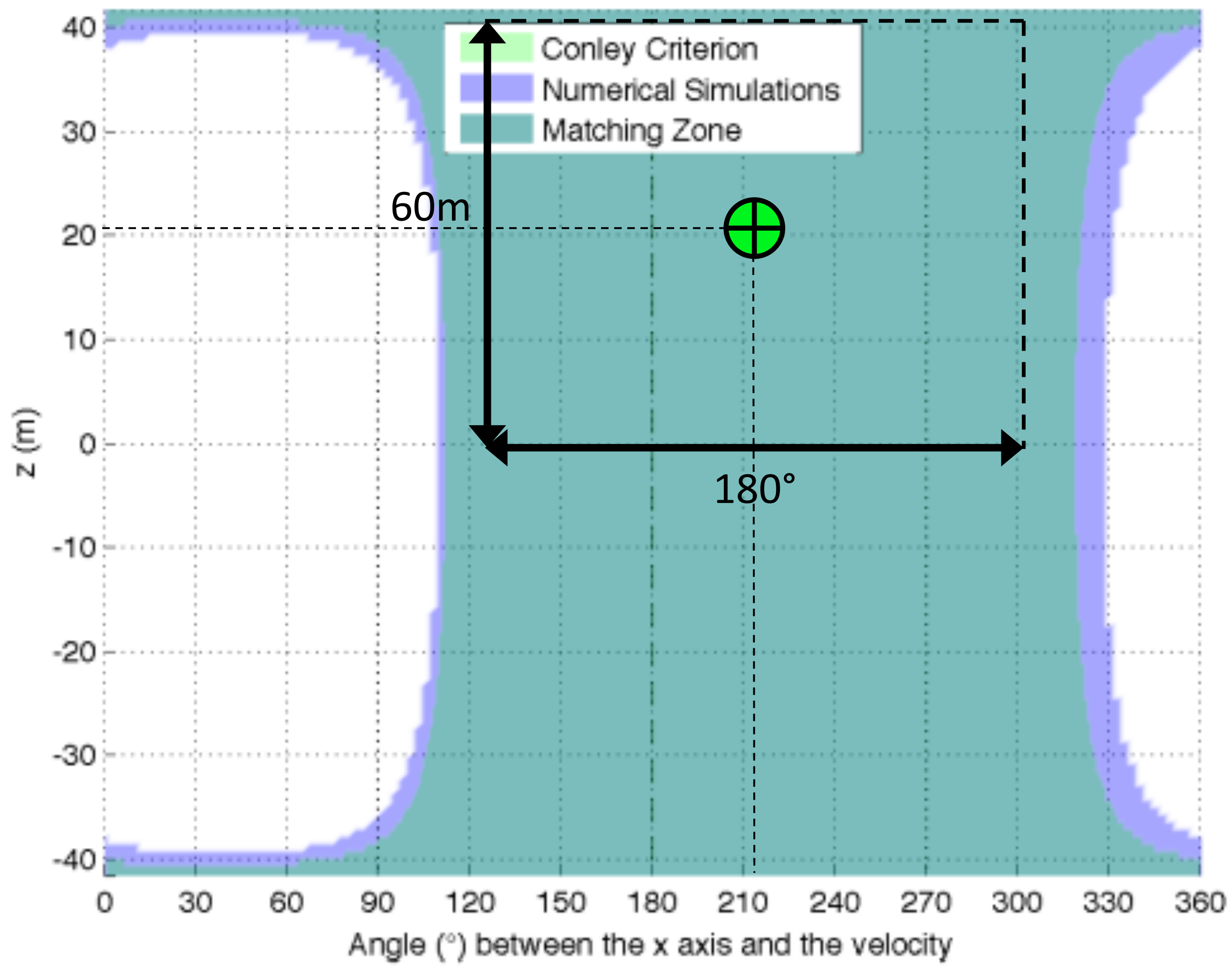
… how can we ensure that our lander will enter this region ?

➔ Following Conley (1968), linearizing at L2, we obtain a criterion on the polar angle of velocity at the neck.

A representation of Conley's criterion



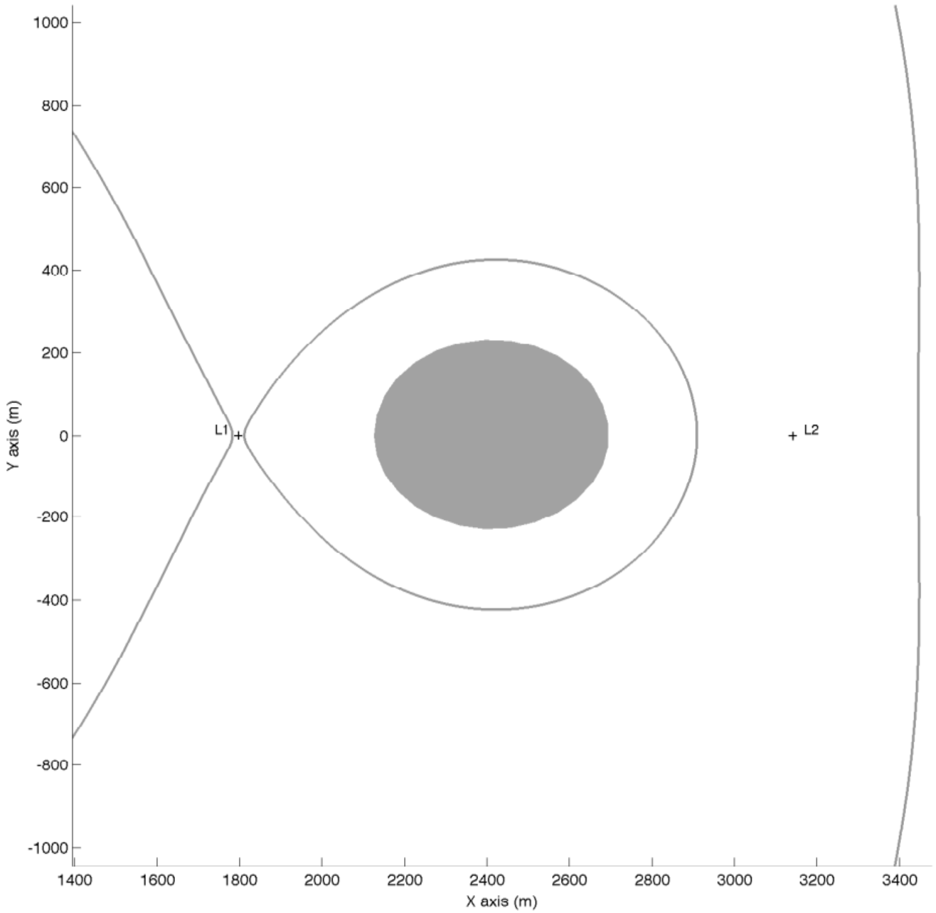
Matching analytics with simulations



Grounding the lander

- We reach the surface… but do we land ?
- Neck closure criterion

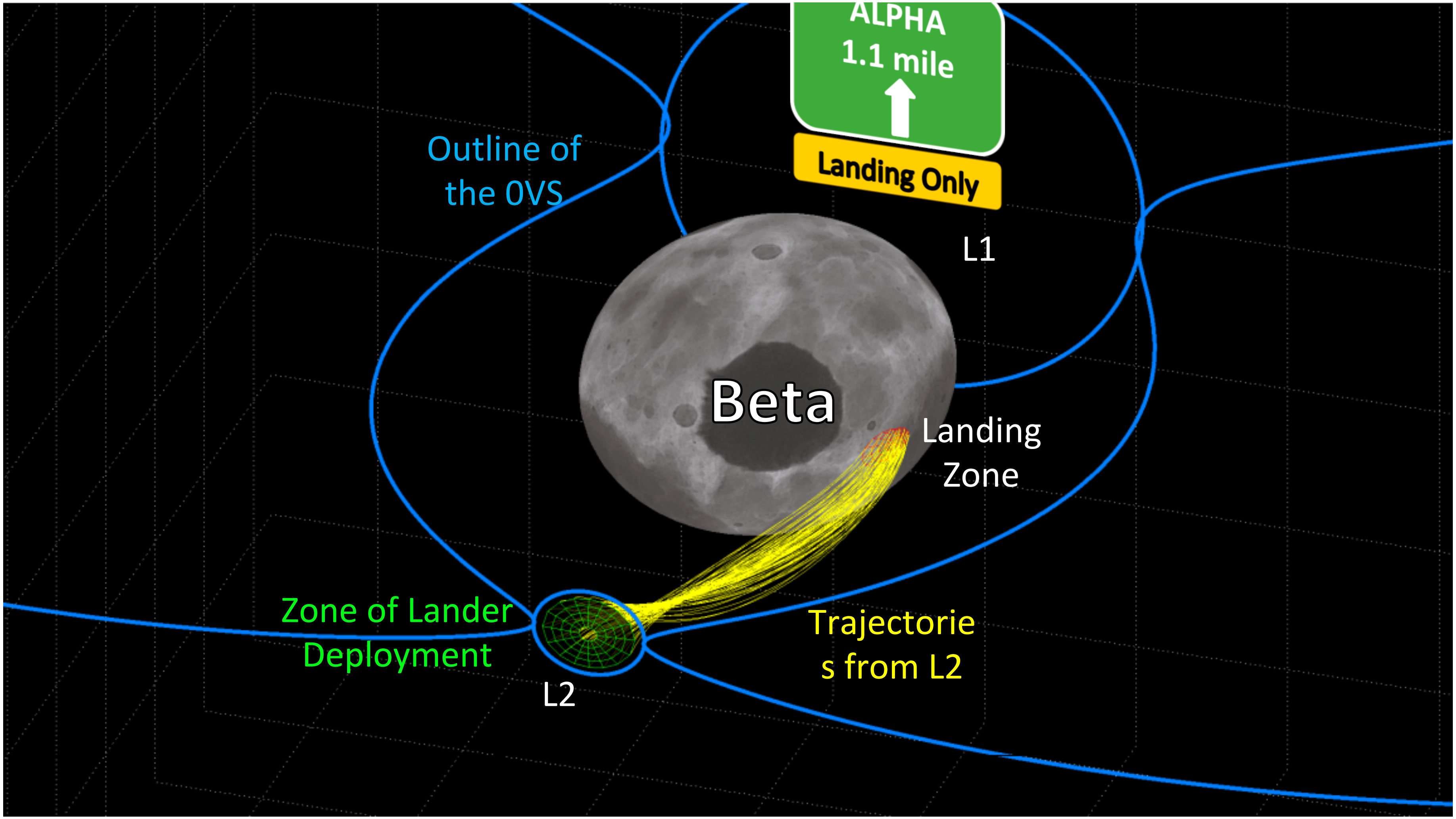
→7% speed damping at impact is sufficient



Main features of the landing strategy

- Landing on the secondary is feasible for the vast majority of binary NEOs.
- The deployment consists in releasing the lander in the L2 neck with a designated velocity direction and speed.
- No GNC needed for the lander.
- No risk for the mothership.
- Margins that applies on deployment conditions are (for KW4) :
  - -100m to +100m on the nominal y-axis release position
  - 0% to 500% error the nominal deployment speed
  - -90° to +90° on the nominal velocity direction

Questions?


ALPHA
1.1 mile
Landing Only
Outline of
the OVS
L1
Beta
Landing
Zone
Zone of Lander
Deployment
L2
Trajectorie
s from L2