Analysis of the descent and bouncing trajectory of Mascot on 1999JU3

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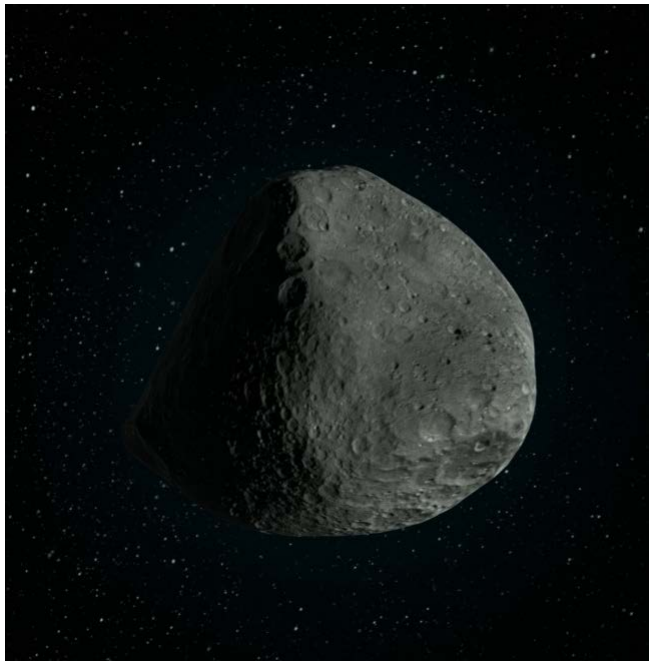
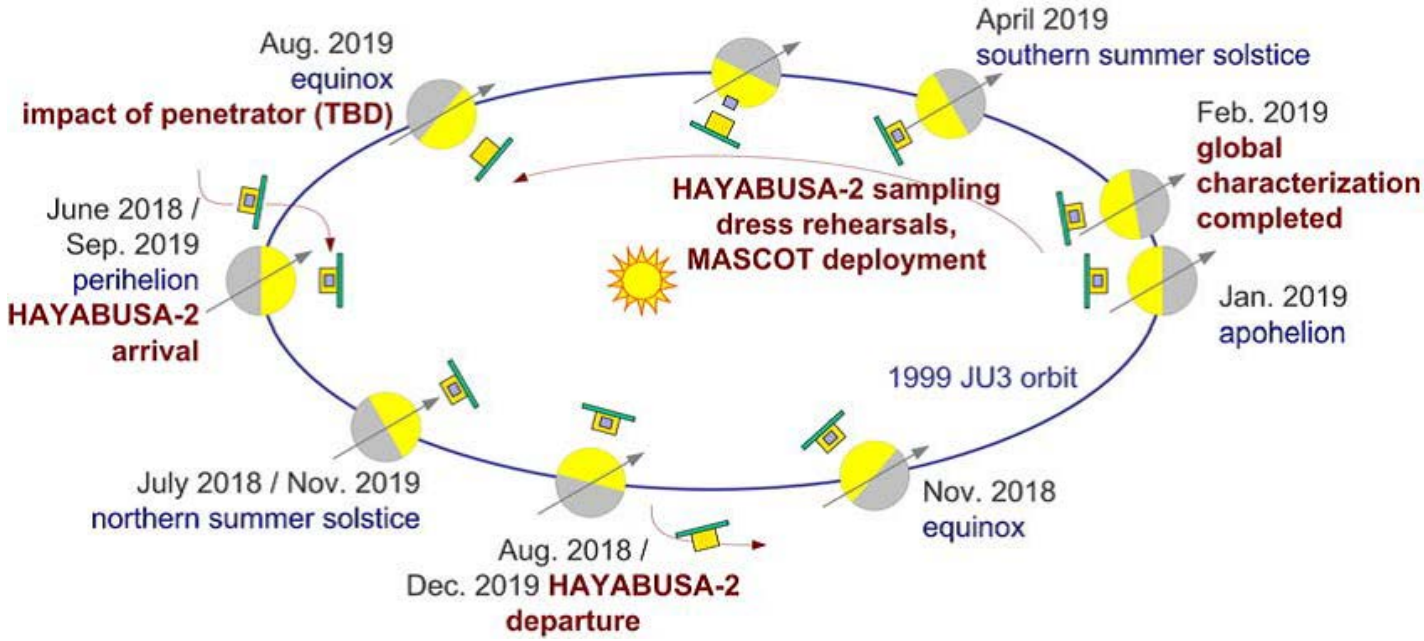
Overview

- Hayabusa-2
- The asteroid: 1999JU3
- The lander Mascot
- Separation from Hayabusa-2
- Descent trajectories
- Touchdown ellipses
- Bouncing after touchdown
- Optimized separation conditions
- Conclusions



Hayabusa-2 mission



- Launch: December 2014
- Arrival at 1999JU3: July 2018
- Impactor experiment (JAXA) Sept 2019

} ➡ Possible separation period August 2018-August 2019

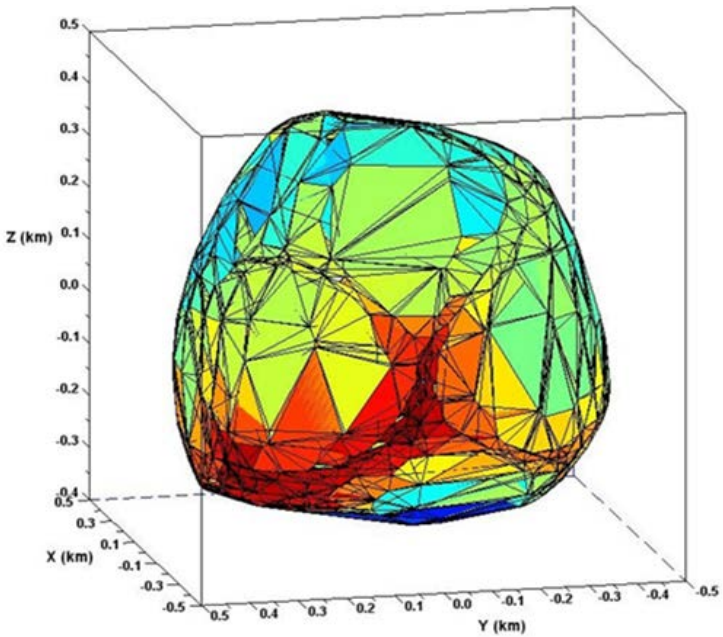
- Return to Earth: July 2020
- Conjunction period 18/11/2018 to 01/01/2019 (angle asteroid-Sun-Earth > 170 deg)

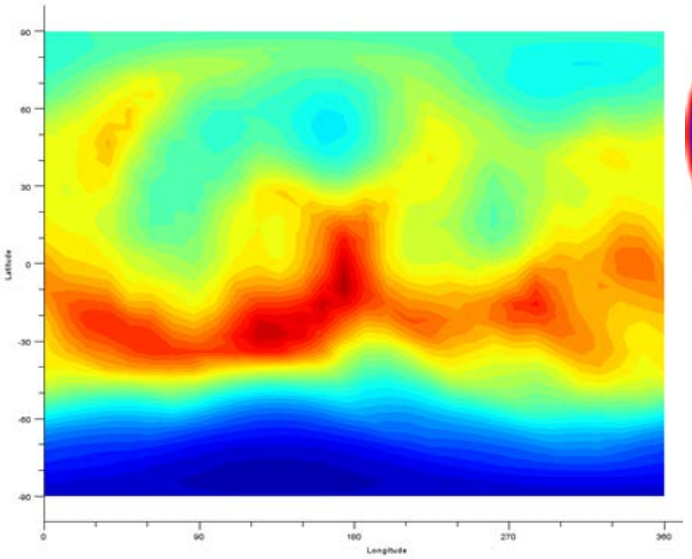
The asteroid 1999JU3

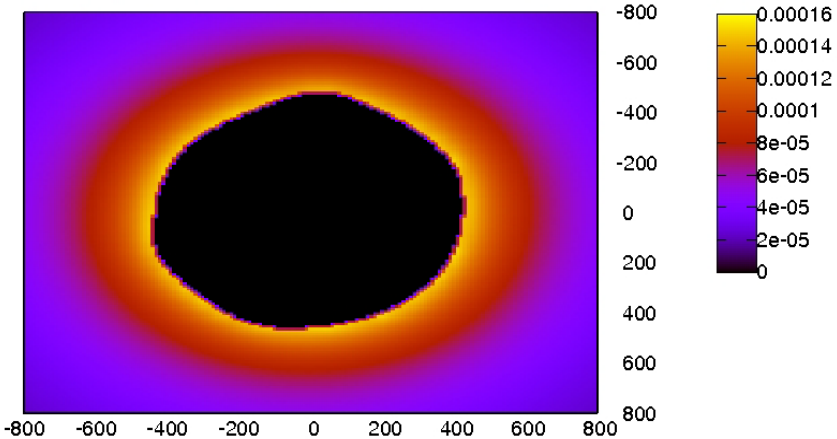
a = 1.2 AU, e = 0.19, i = 5.88 deg

(pericentre 0.96 AU, apocentre 1.4 AU)

Period = 473.86 days ~1.3 years

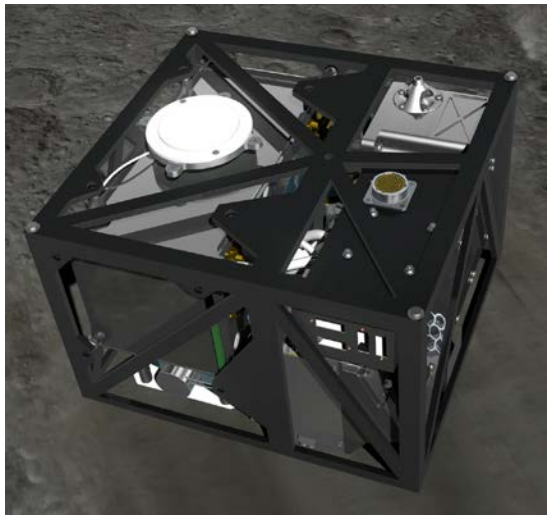




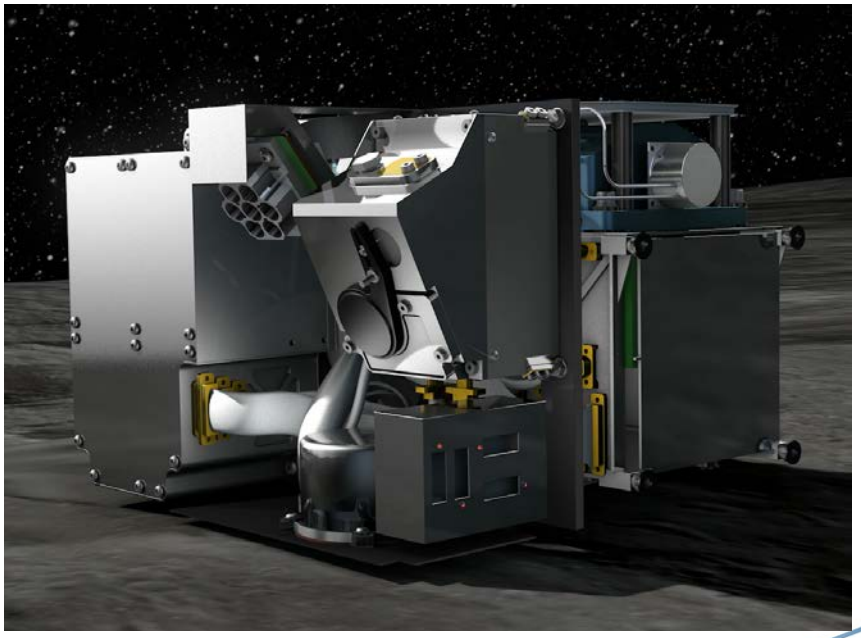


Equivalent radius	435 m	**Density** (constant)	1390 kg/m^3
Minimum radius	374 m	**Spin axis** (*Müller model, 2011*)	λ_{ecl} = 73.1 deg, β_{ecl} = -62.3 deg
Maximum radius	495 m	**Rotation period**	7.63 h

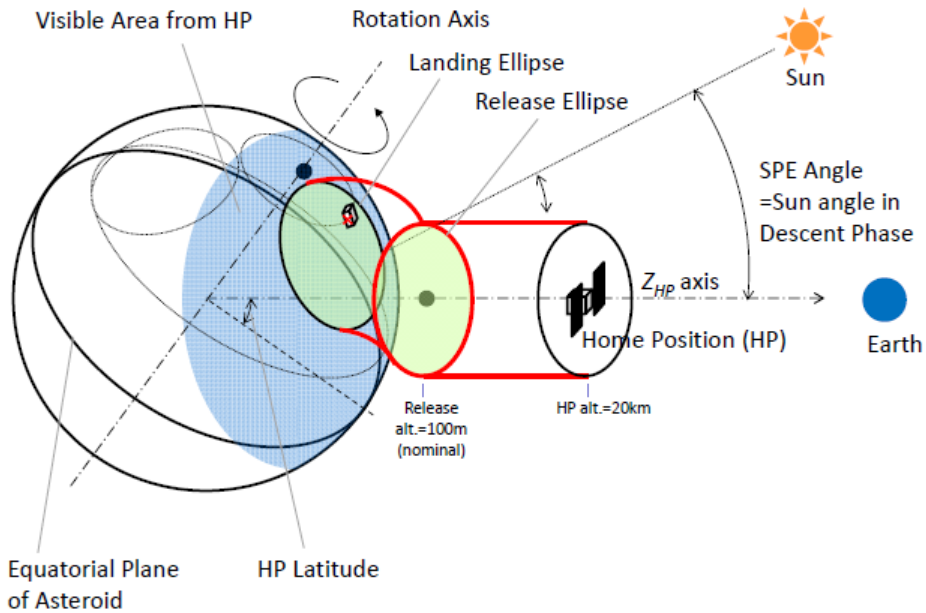
Mascot

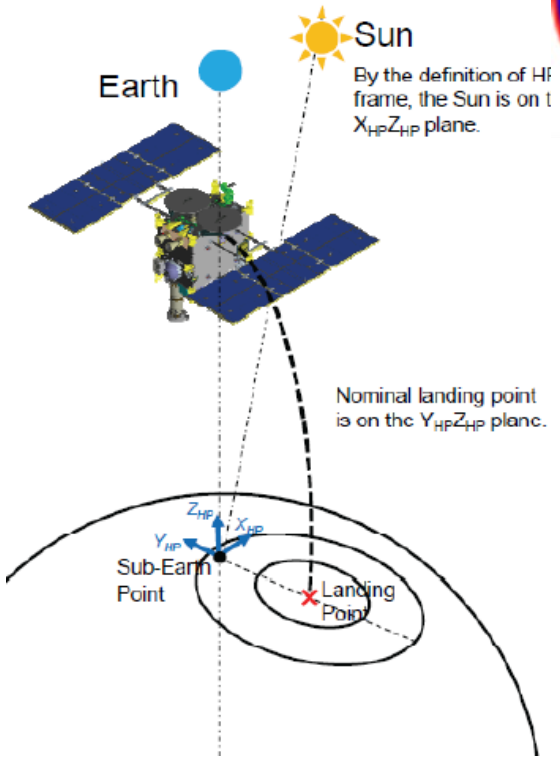


- Weight ≈ 10 kg
- Instruments:
  - Infrared microscope (MircroOmega)
  - Radiometer (MARA)
  - Magnetometer (MAG)
  - Wide Angle Camera (CAM)
- No propulsion system
- No direct commanding (autonomous)
- No anchoring on the surface
- 12h lifetime
- Perform science in more than one site (mobility system)



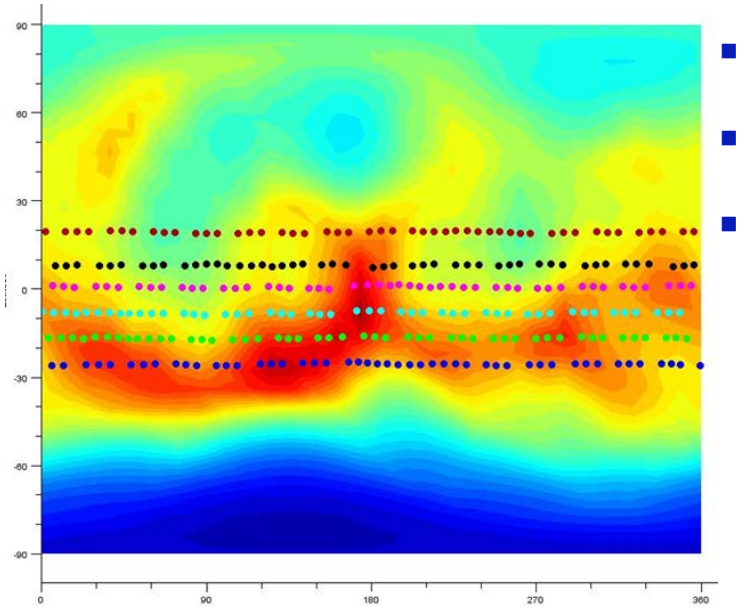
Separation from Hayabusa-2





- Hayabusa-2 Home Position (HP): line asteroid to Earth, 20km from 1999JU3
- HB-2 descends to separation altitude (100 m), delivers MASCOT and returns to HP.
- Separation attitude: $+Z_{HP}$ pointing to the Earth (HGA), $+X_{HP}$ in the Earth-asteroid-Sun plane
- MASCOT is mounted under –Y panel and separates with an angle of 15 deg
- Separation ΔV = 5 cm/s

Descent trajectories



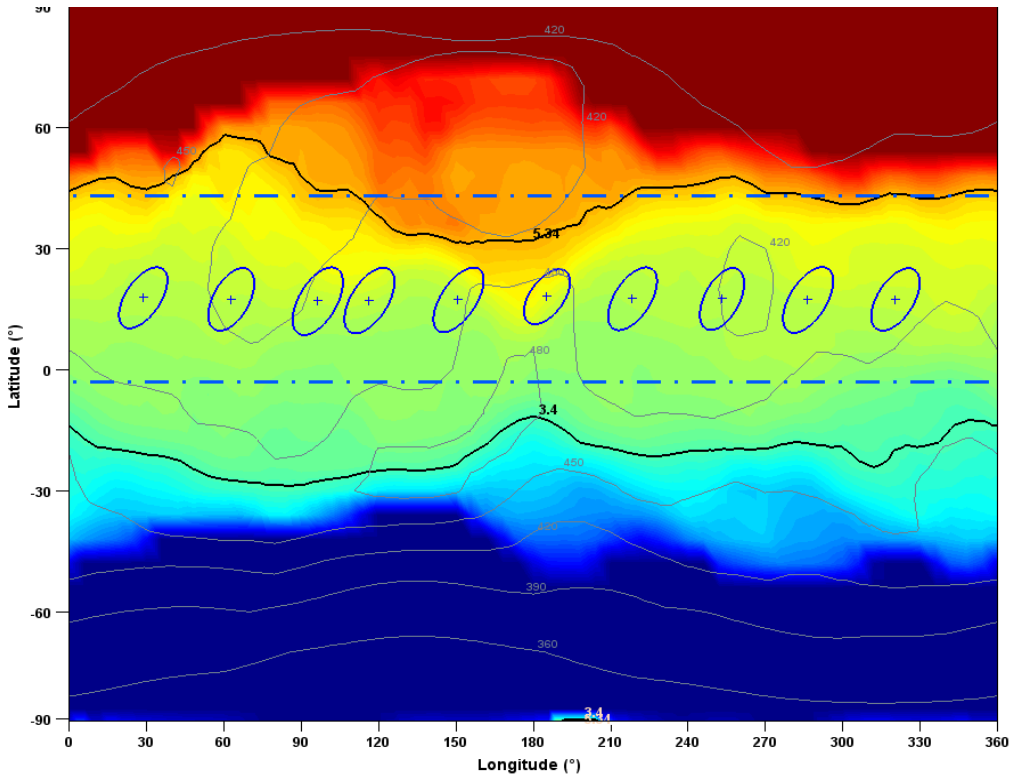
- Nominal touchdown sites ± 45 deg
- Descent times of 20 to 30 minutes
- Constraints:
  - Impact velocity at first TD < ½ escape velocity
  - Daylight duration 50% to 70% of the period T
  - RF visibility of Mascot from S/C > 40% of T
  - Thermal constraints

Dispersion analysis

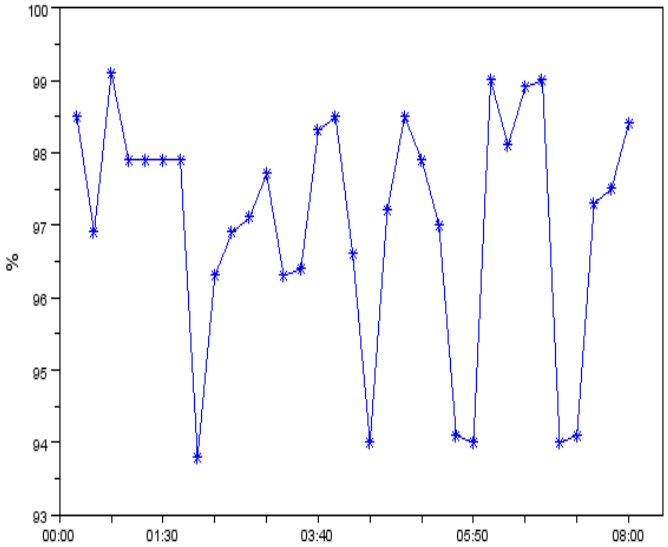
HYB-2 Position	Vertical direction (asteroid to Earth axis)	3σ= 13.3 m
	Horizontal direction	3σ= 33.3 m
HYB-2 Velocity	Vertical direction	3σ= 1.66 cm/s
	Horizontal direction	3σ= 1.55 cm/s
HYB-2 Attitude	In the 3 axis	3σ= 0.1 deg
Separation Δv	Magnitude (uniform distribution)	± 1 cm/s
	Direction	3σ= 1.5 deg
Gravity of 1999JU3	Uniform distribution	70% - 130%

Touchdown ellipses

Separation date	Nominal Touchdown latitude (deg)	Angle with respect to a fixed latitude value (deg)	Latitude band (± around nominal TD latitude)	A Semi-major axis		B Semi-minor axis	
				deg	m	deg	m
20/01/2019	19	36	**± 6.5**	11	83.5	6	45.5
30/03/2019	0	30	**± 6**	10.02	75.92	5.71	43.35
20/06/2019	-21	31	**± 7.2**	14	106.3	5.96	45.25



% v_imp constraint fulfillment



Bouncing after touchdown

Normal force: e

Friction force: c_f

Rolling resistance: c_{rr}

+

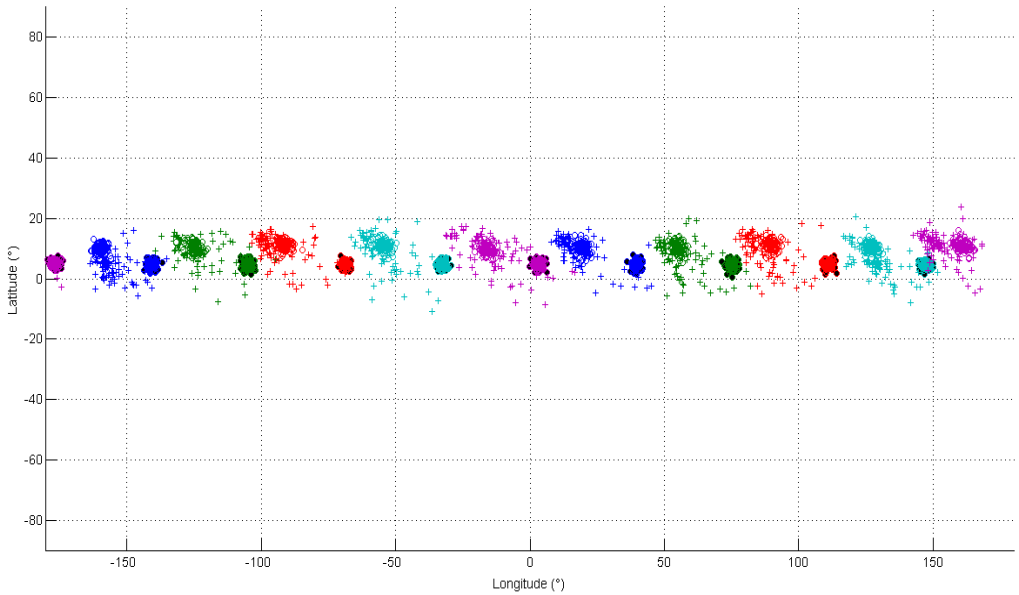
Characteristics of the surface

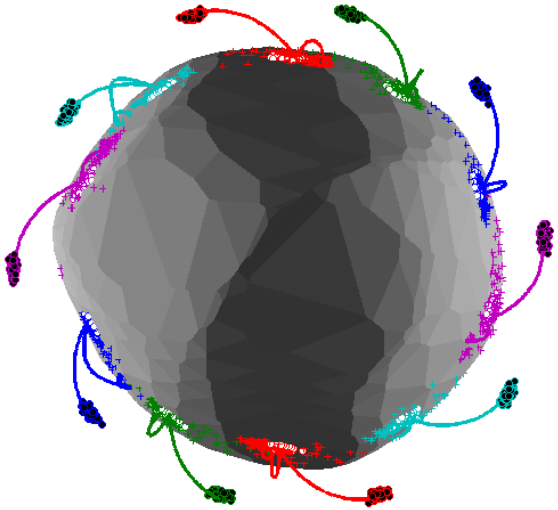
Characteristics of lander

Rock distribution

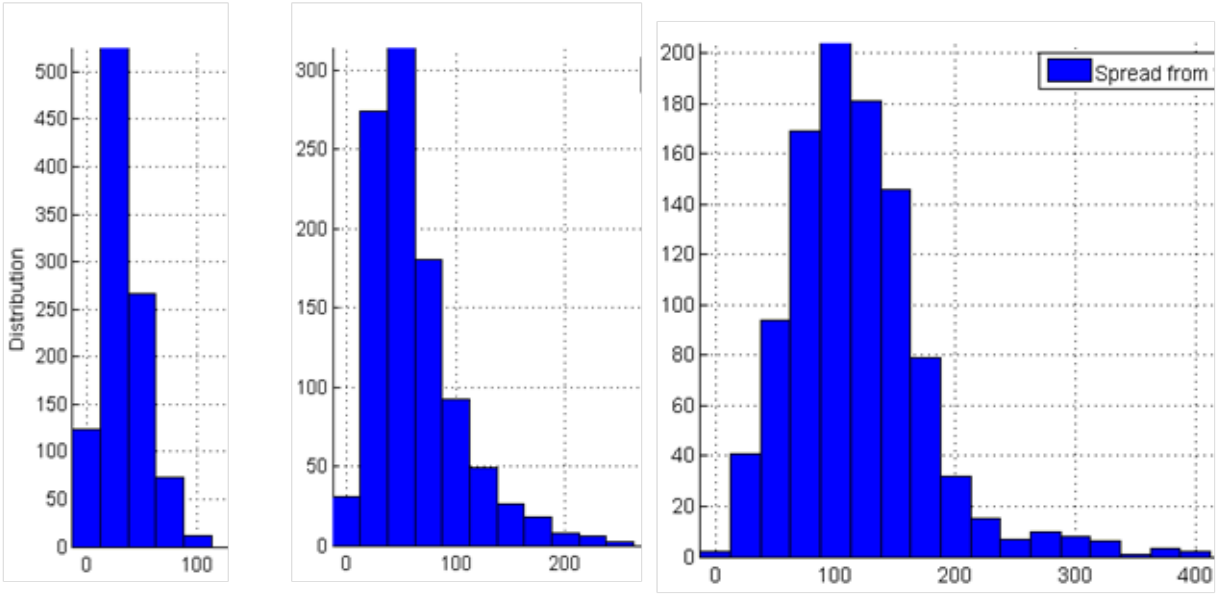
Random collision model

<u>Example</u>: 30/03/2019, e = 0.65, c_f = 0.5, c_{rr} = 0.25 (Model by S. Tardivel)

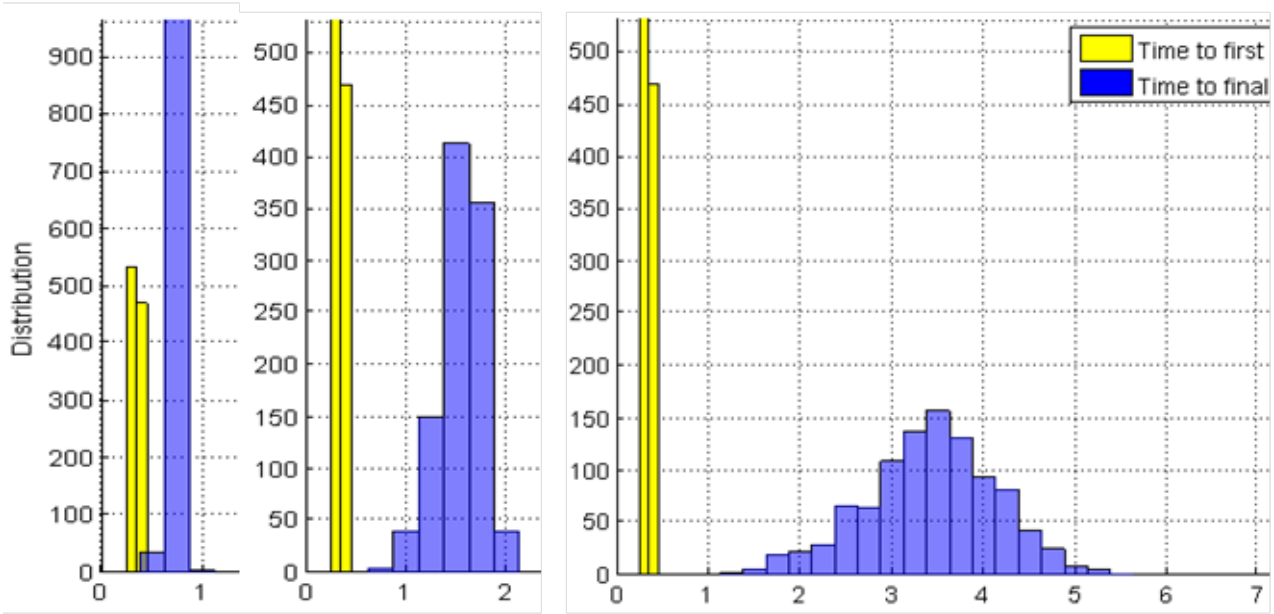




Bouncing after touchdown (II)



0.35 0.65 0.85

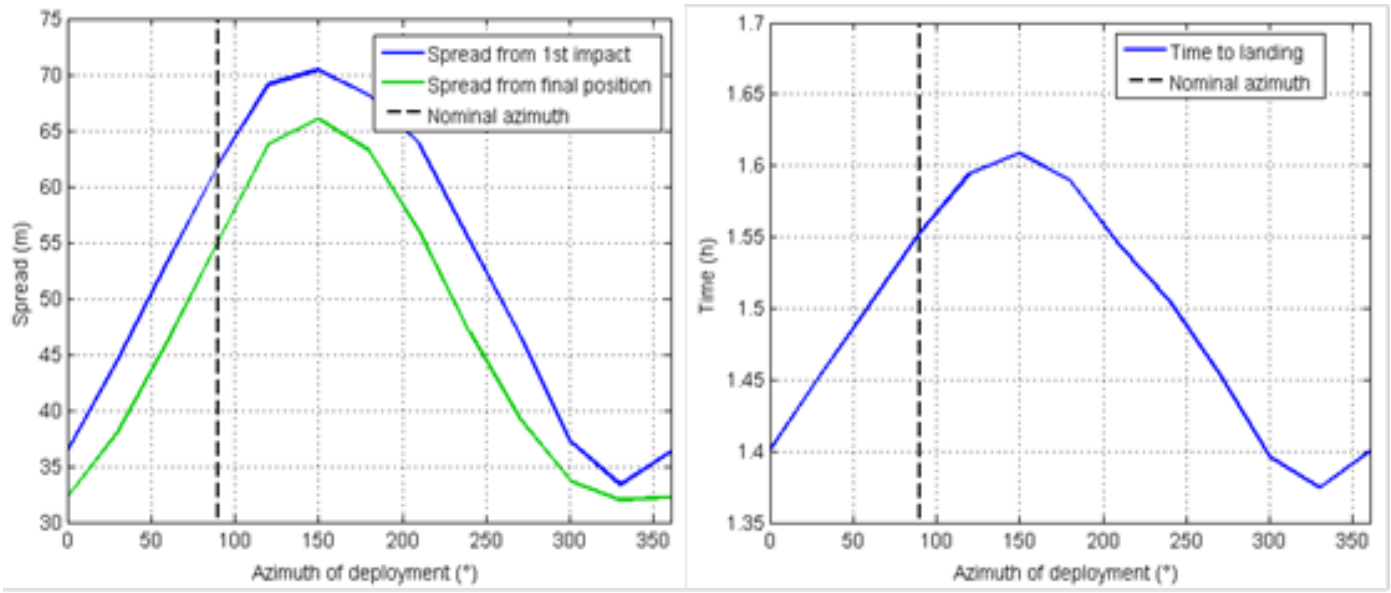


Restitution 0.35
Mean distance = 55 m
Max distance ~ 100 m
Bouncing times: 20-40 min
Total time < 1h

Restitution 0.65
Mean distance = 70 m
Max distance ~ 200 m
Bouncing times: 30-90 min
Total time < 2h

Restitution = 0.85
Mean distance = 110 m
Max distance ~ 400 m
Bouncing times: 1.2 - 4.5h
Total time < 5h

Bouncing: Optimized separation attitude



- +Z axis of Hayabusa-2 towards Earth (HGA): rotations around +Z
- Best separation conditions: tangential impact velocity close to surface rotation
- Improvement in terms of bouncing time (10 minutes) and distance (40%)

Conclusions

- Mascot is healthy and safely flying towards 1999JU3
- Complete mission analysis for descent trajectories has been performed at CNES
- Simulations of the bouncing trajectory thanks to a collaboration with S. Tardivel
- Work to be done concerning the interaction between surface and lander and the complete dispersion analysis including descent and bouncing
- Asteroid phase in 2018 will reveal key informations to update the analysis and support the choice of the separation date and time

Thank you for your attention!

JAXA

DLR

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