Planet-D mission to Venus in the future

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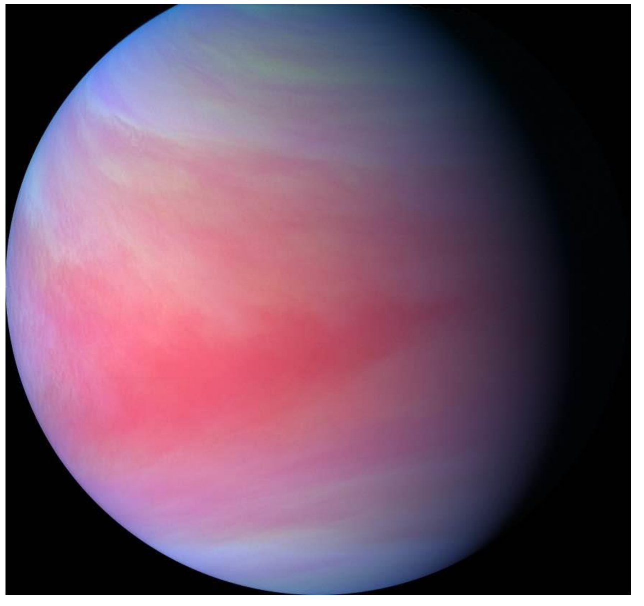
Example images taken by Akatsuki cameras (IR1, IR2, UVI, LIR)

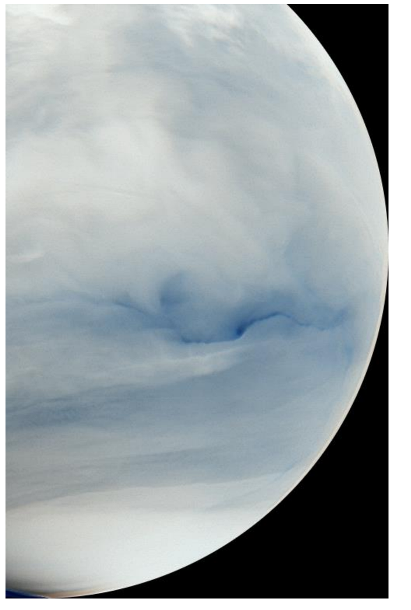
A synthesized false color image

(283 nm : blue;
365 nm : green;
0.90 µm : red.)



IR1,UVI

Y shape structure clearly appears



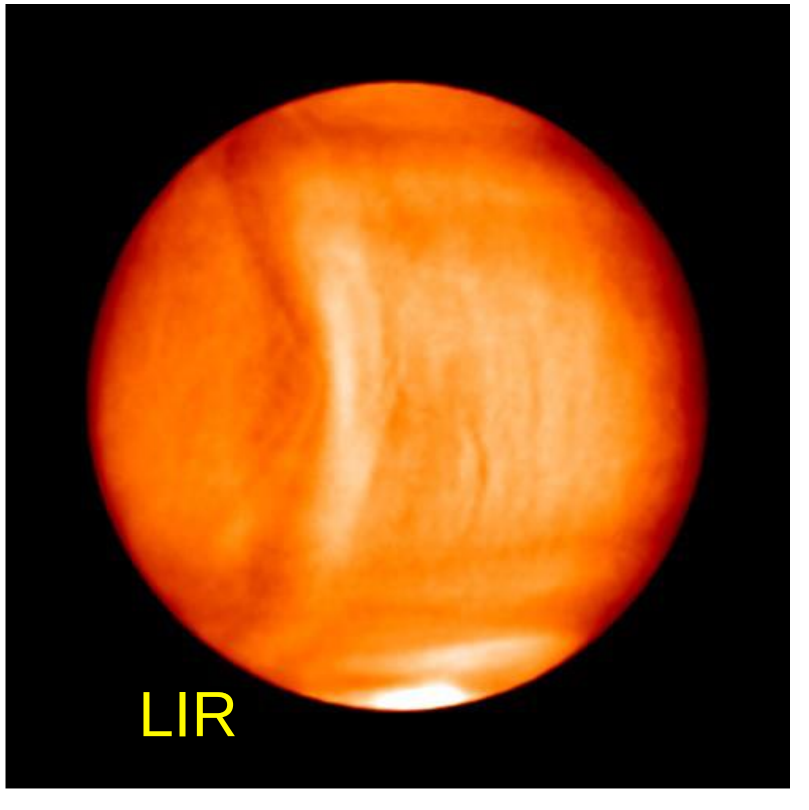
IR2

Venus nightside clouds at the deep cloud layer.

(brightness inverted)

1.735 µm(blue) and 2.26 µm (red)

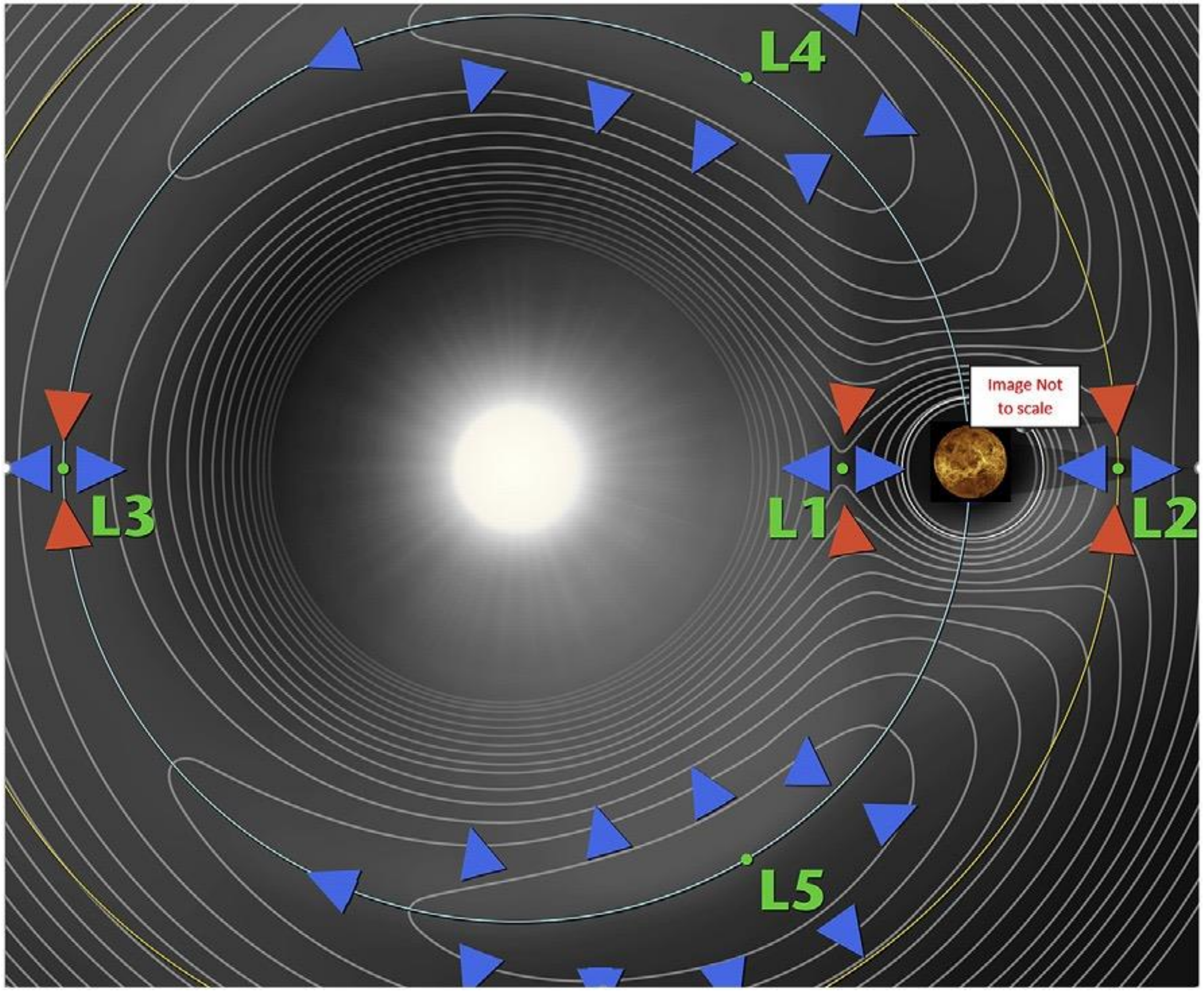
cloud top temperature taken by LIR. A huge bow shape structure is seen.



Images	
IR1:	1,643
IR2:	3,201
UVI:	17,306
LIR:	31,444

by Jan. 2, 2020

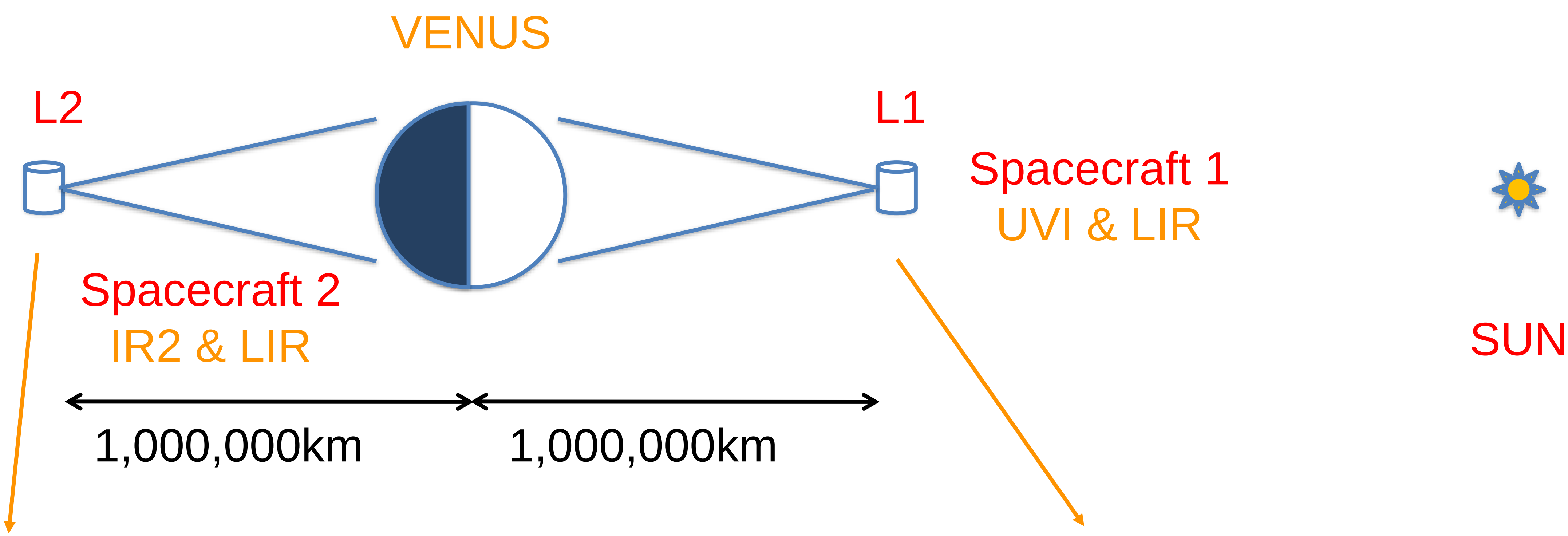
Mission to Lagrange points

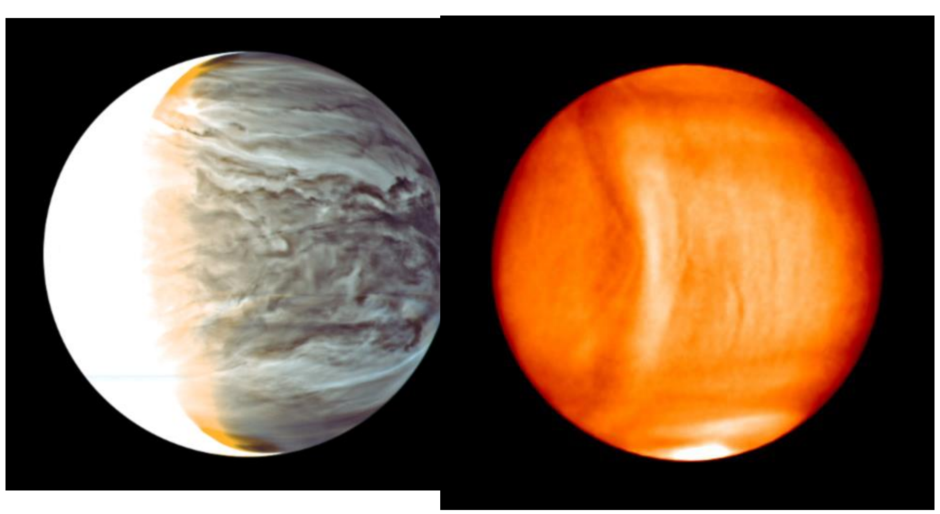


Lyapunov orbit
or
Lissajous orbit
or
Halo orbit

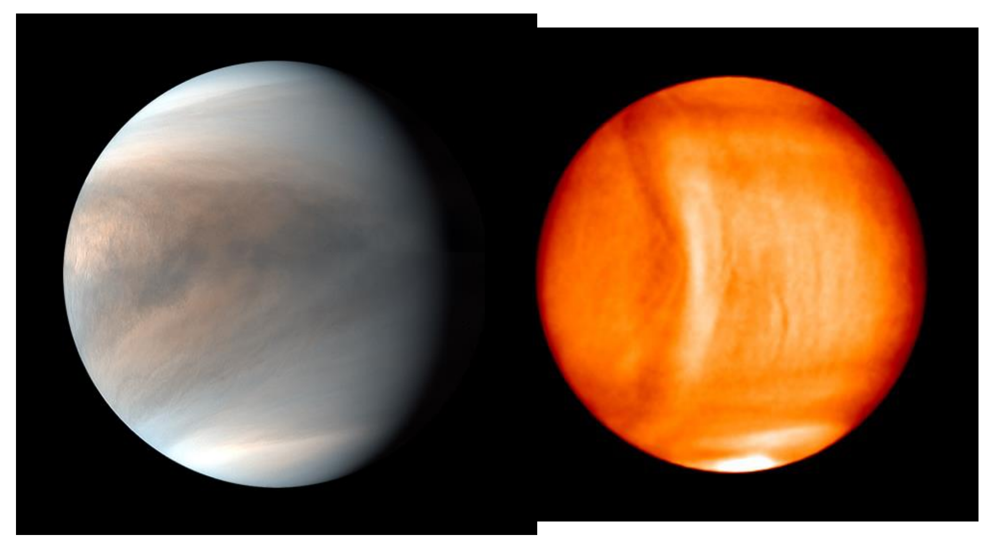
around Lagrange points

Planet-D concept





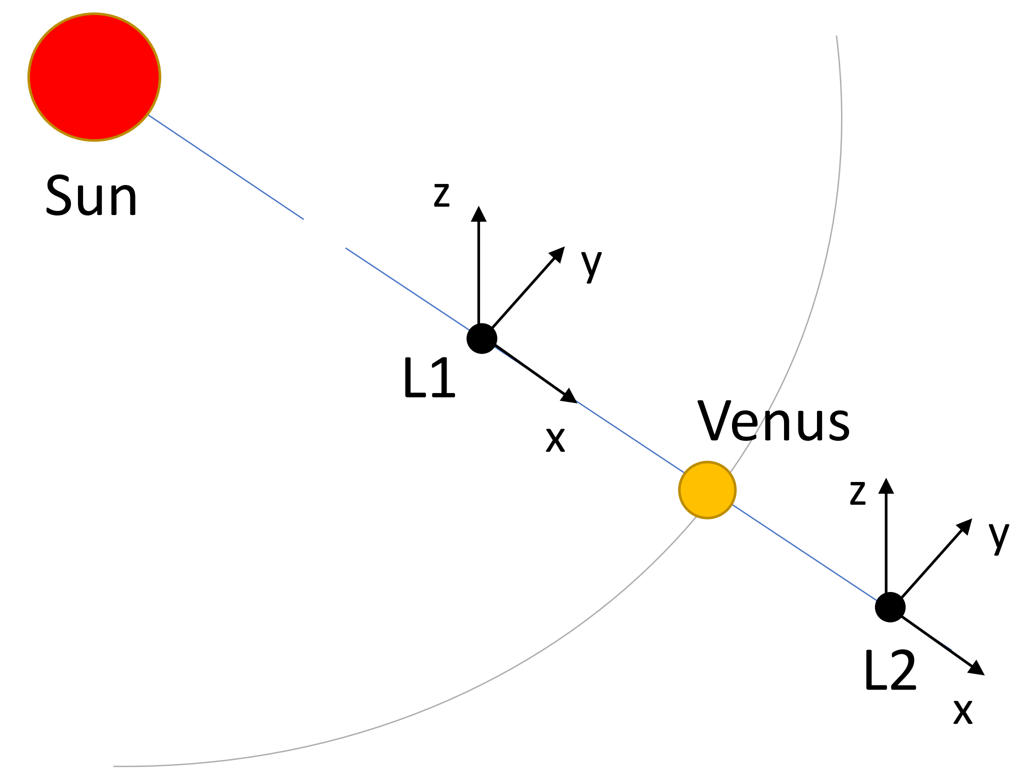
Night side imaging

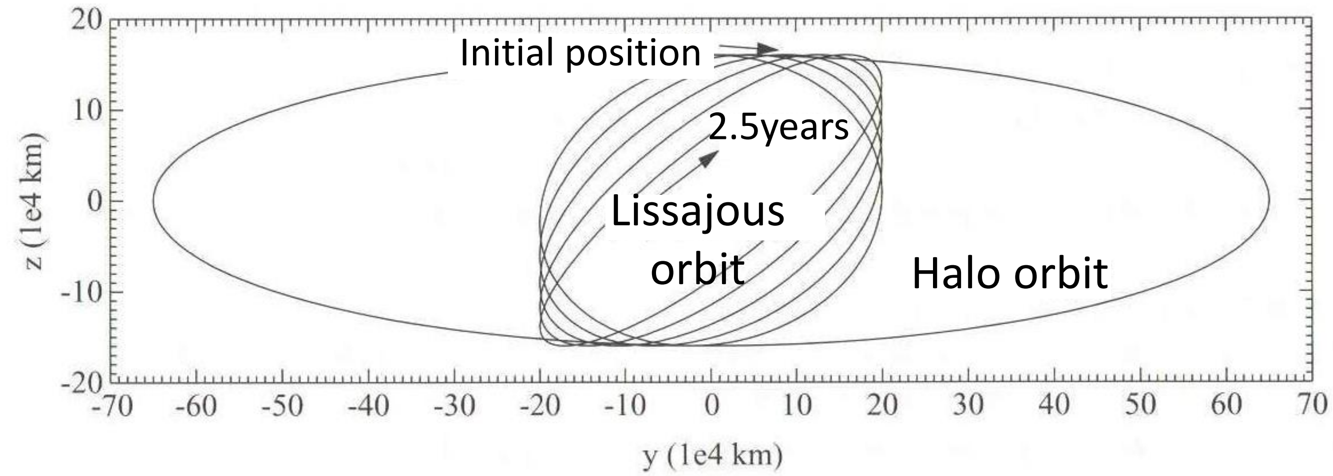


Day side imaging

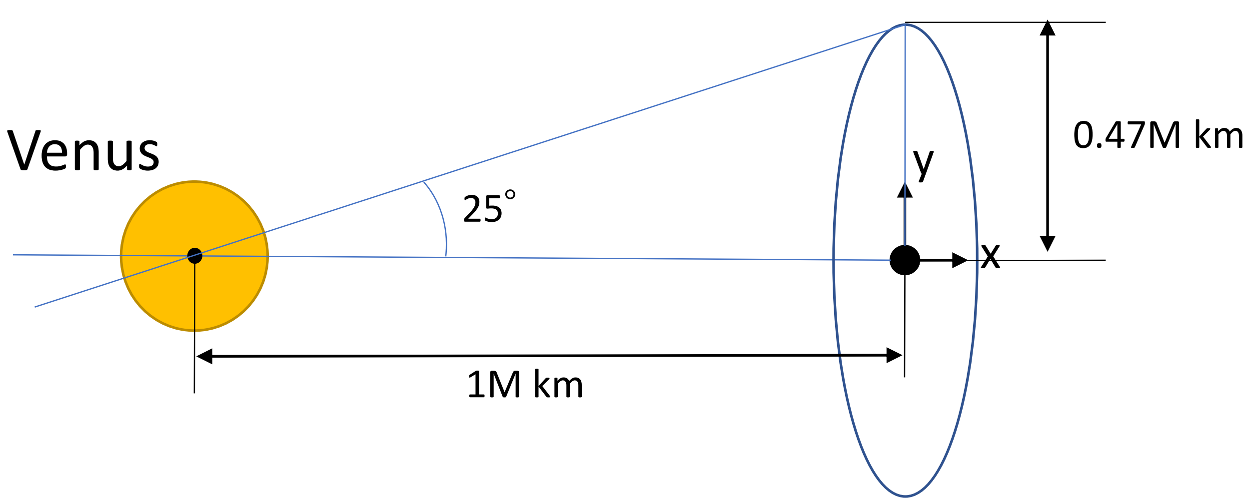
- We will be able to watch both dayside and nightside simultaneously
- We need much more IR2 images at nightside (1643 images << 31,444 LIR images from Akatsuki)

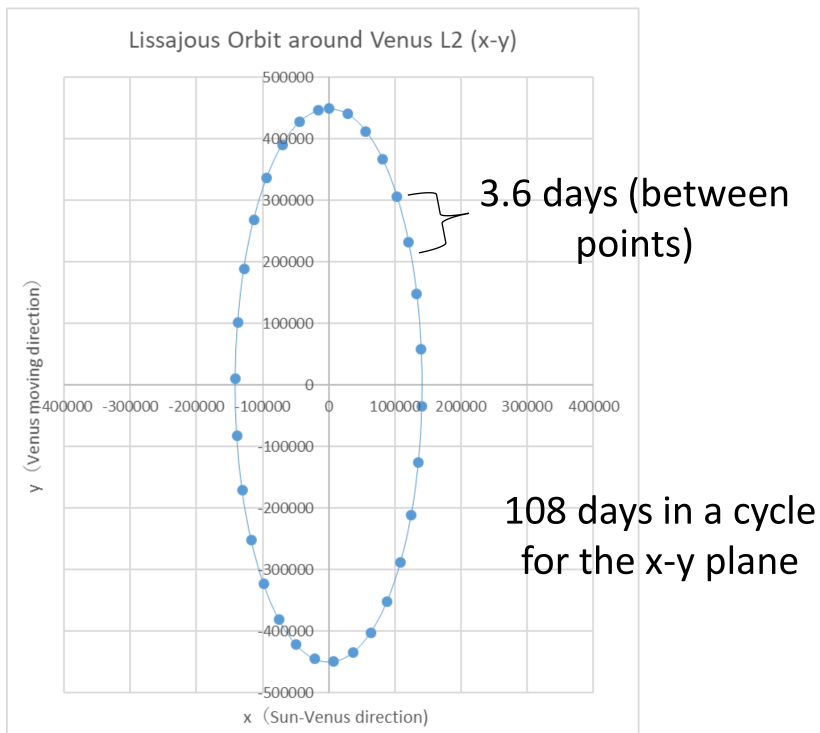
The orbits around Venus L1 and L2



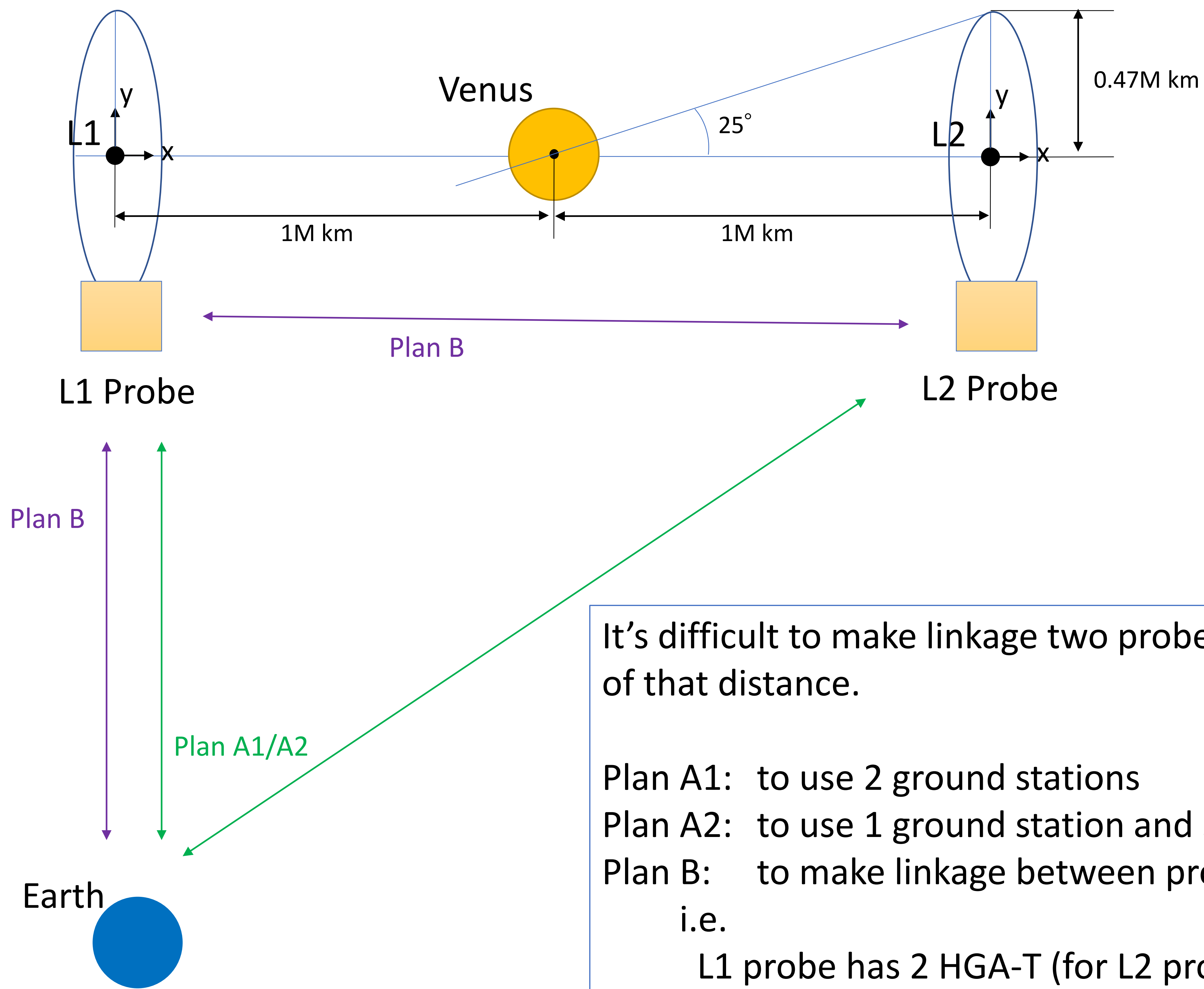


To make angle to the Venus 25deg, the semimajor axis must be under 0.5M km.
Because Halo orbit has minimum length for z direction in theory, Lissajous orbit is preferable.
(The graph above is for Sun-Earth L-point)





Telemetry



It's difficult to make linkage two probes simultaneously because of that distance.

Plan A1: to use 2 ground stations
Plan A2: to use 1 ground station and share by time
Plan B: to make linkage between probes
i.e.
L1 probe has 2 HGA-T (for L2 probe & the ground station)
L2 probe has 1 HGA-T (for L1 probe)

Sequence to orbital insertion

1. Insertion to elliptical orbit by Epsilon S (*1) + Kick Stage (*2)

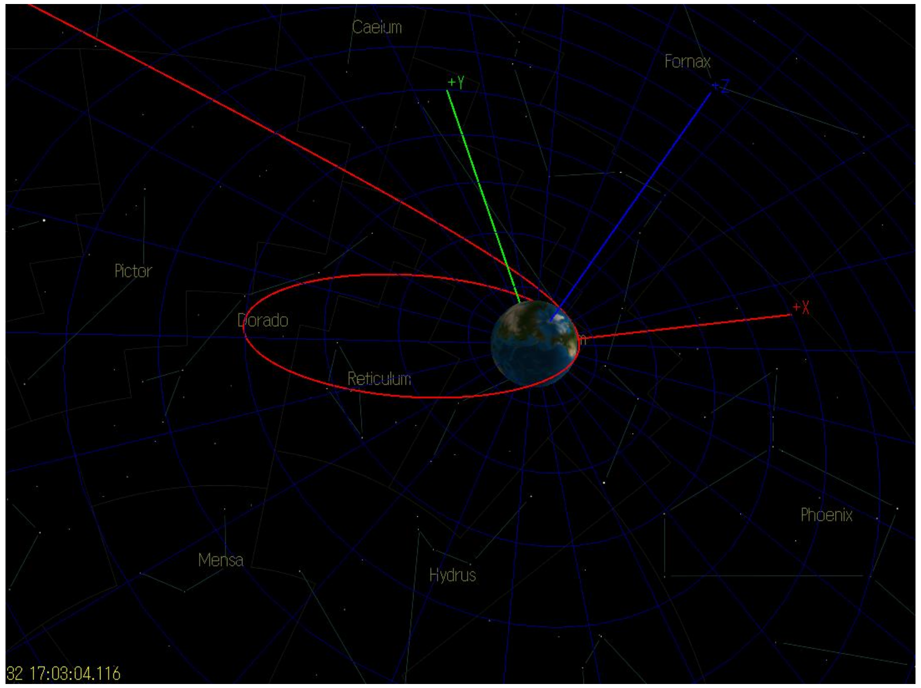
2. Transfer to Earth-Venus interplanetary trajectory

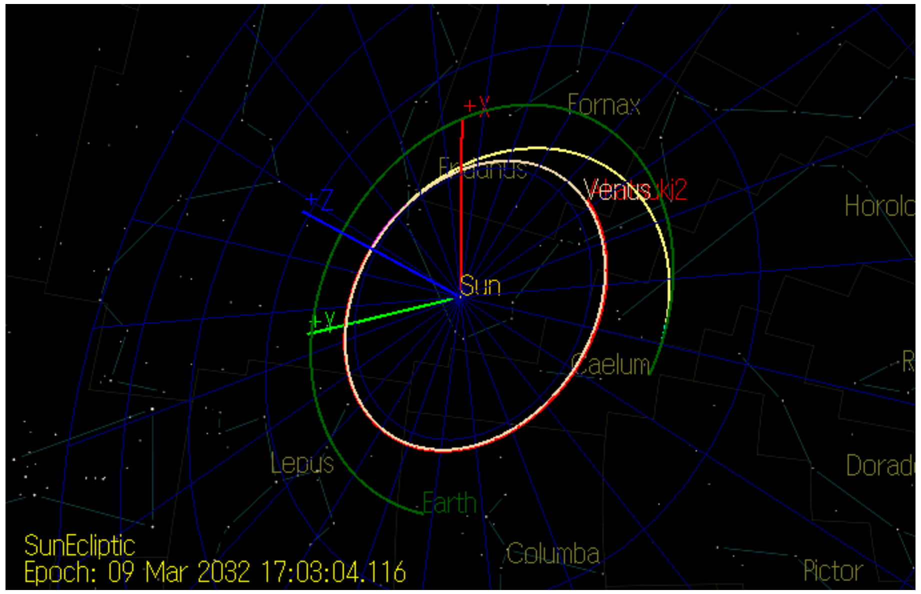
3. Transfer to Venus L1 Lissajous orbit

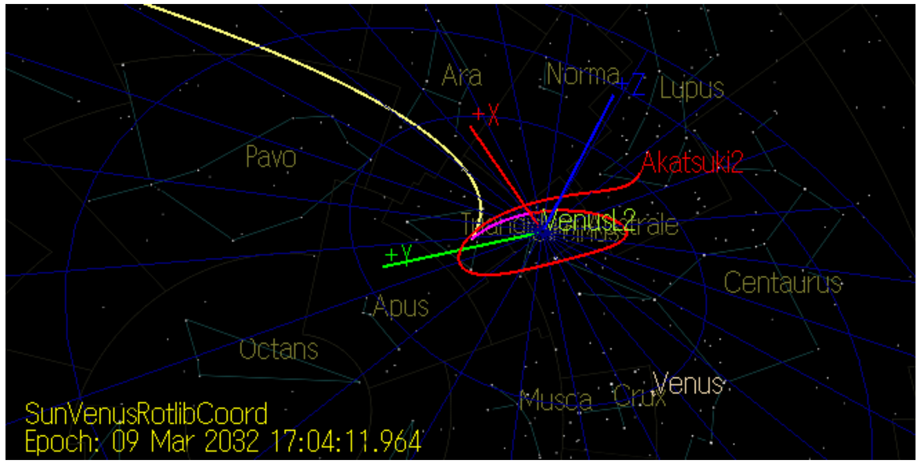
4. Planet-D2 separation from Planet-D1

5. Planet-D2 Transfer to Venus L2 Lissajous orbit

6. Station keeping of Planet-D1 around Venus L1 and Planet-D2 around Venus L2





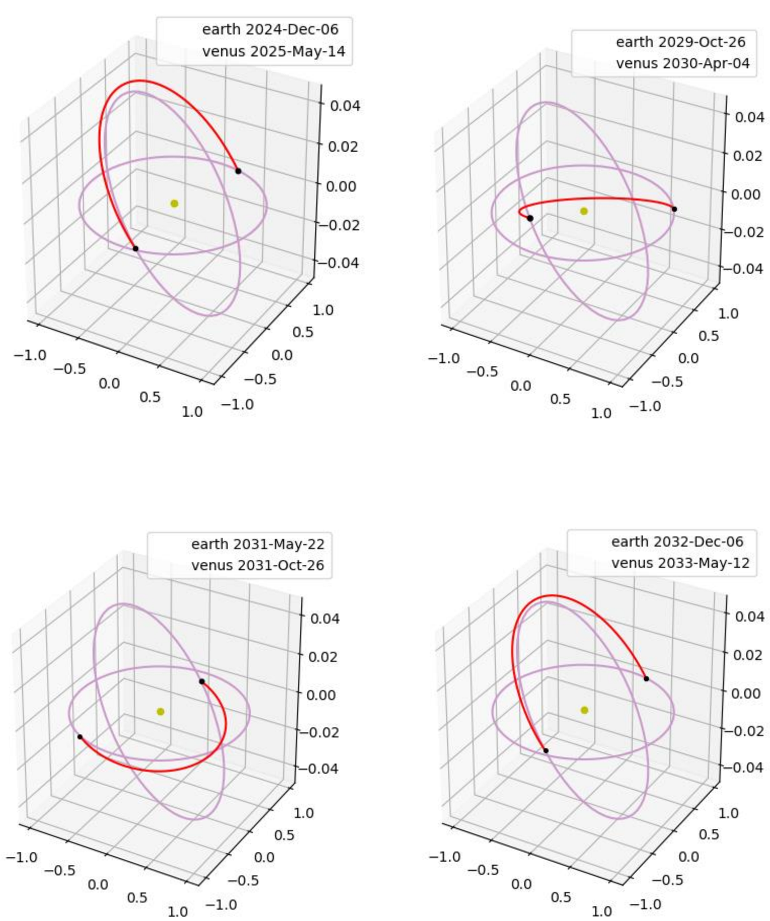


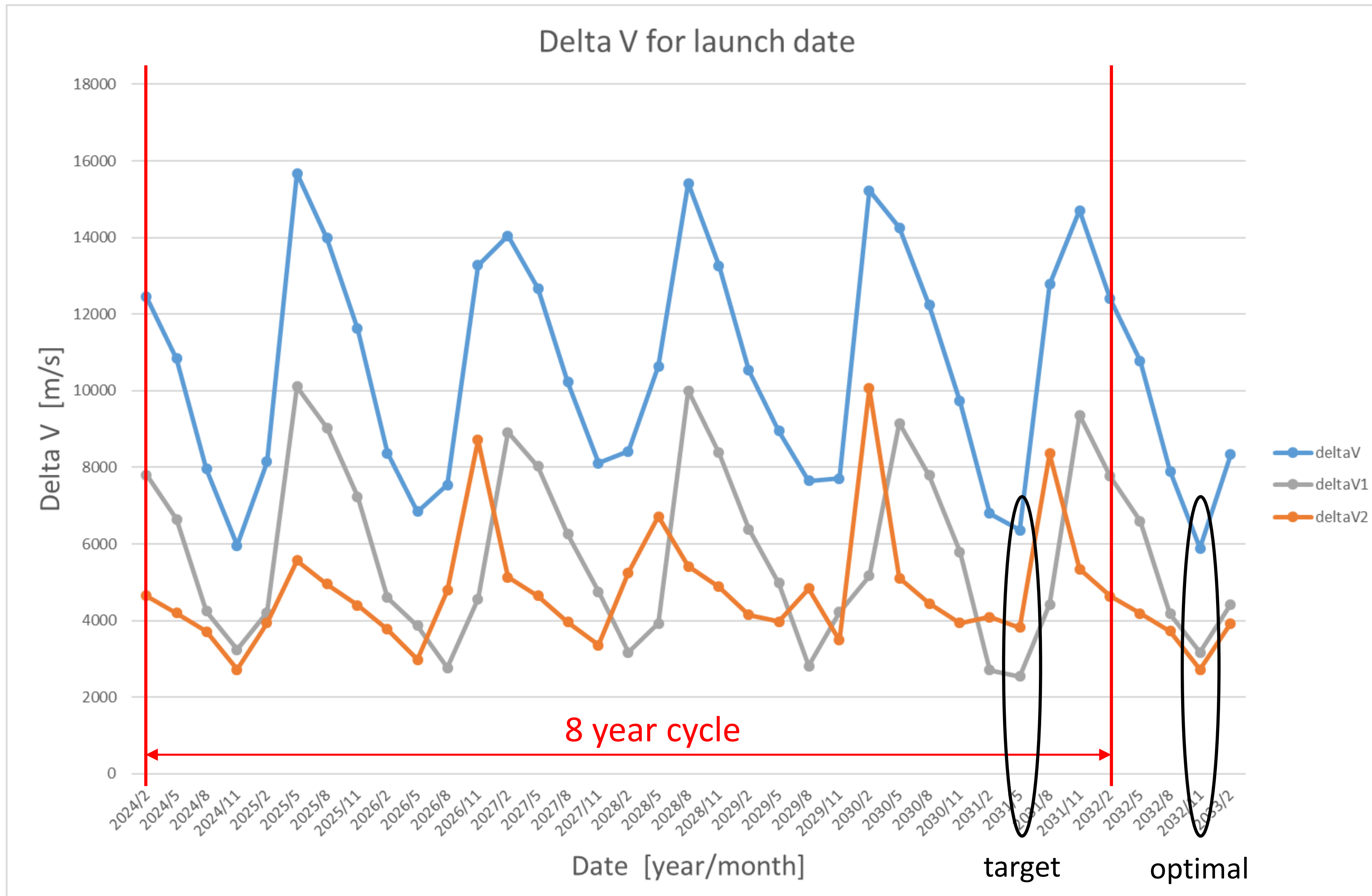
*1 Epsilon S: Improvement of the current Epsilon Launch Vehicle
Development started in 2020

*2 Kick Stage: Under development for Destiny+

Launch period

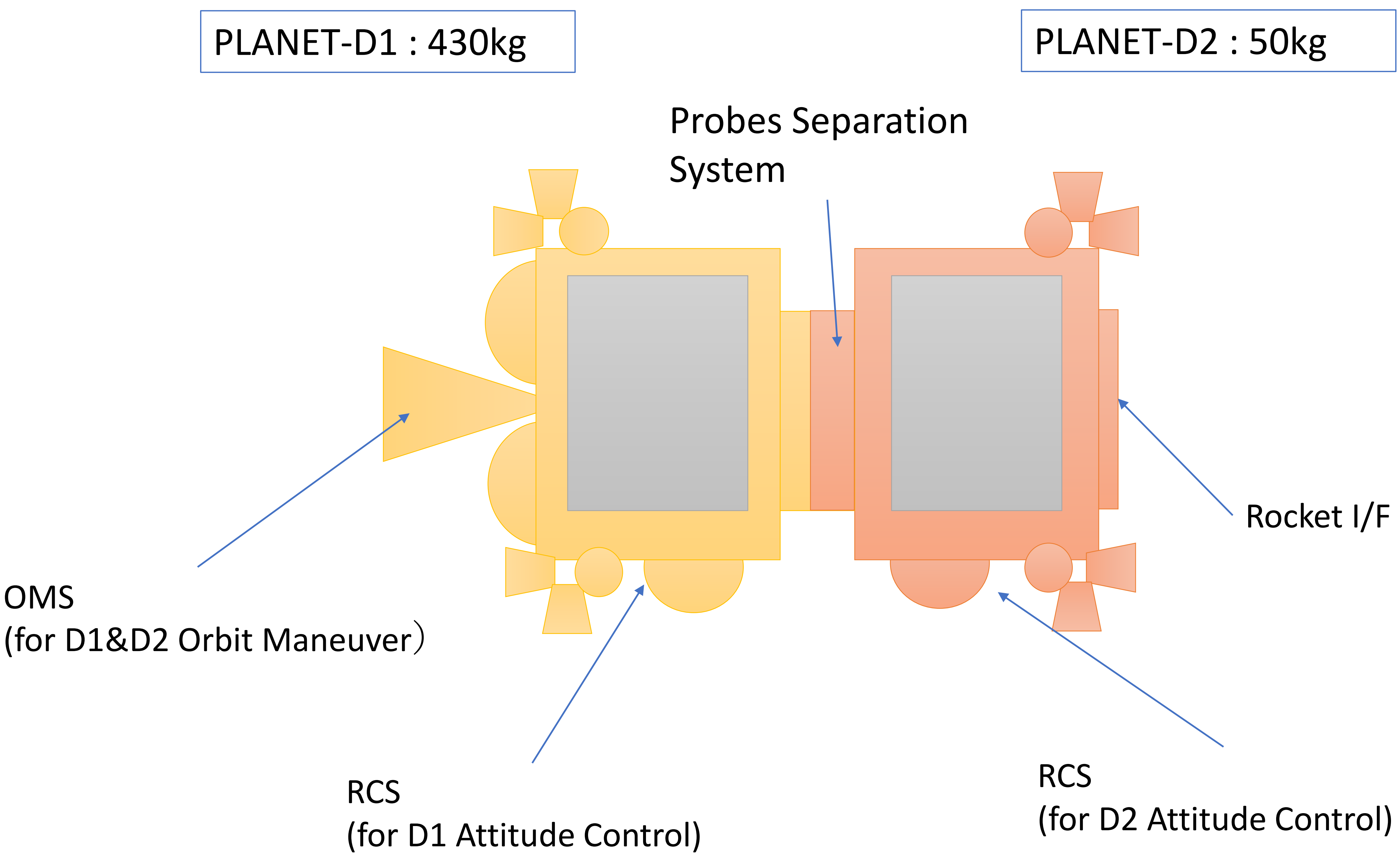
The launch opportunity comes every 584 days, the period of Venus’ meeting with Earth.
However, since the orbital planes of Venus and Earth are tilted, the optimal timing comes every 8 years (about 2920 days ≒ 5 times the meeting period).





If sufficient development time is kept, the optimal period is autumn 2032. However, considering the risk of development delays, the provisional target is spring 2031.
Since this is a point-to-point analysis, it is necessary to examine detailed elements such as Right Ascension of Ascending Node.

PLANETーD Configuration (without mission devices)



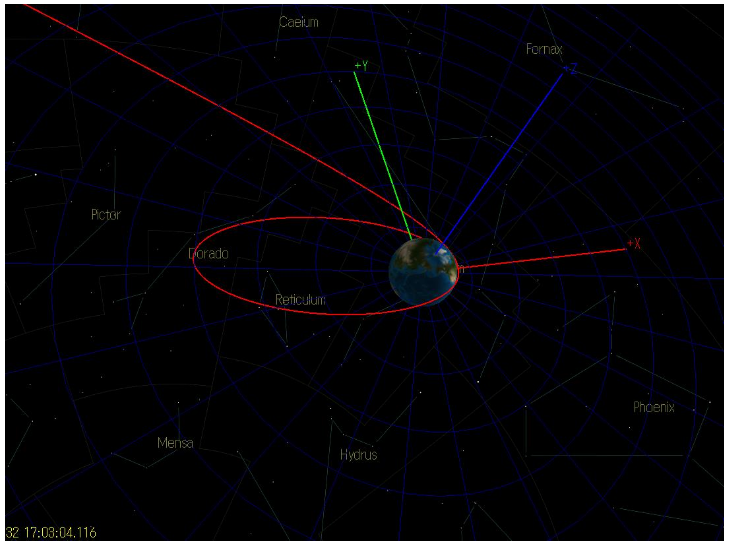
Delta V Estimation

- Results of the analysis

Earth

orbit: alt.230 x 37000km — Payload 480kg

Launch Vehicle (+ Kick Stage)



ΔVevt (1460m/s) by OMC

Earth-Venus transfer orbit

ΔVs (200m/s) by OMC

Venus flyby at 400km altitude

ΔVL (520m/s) by OMC

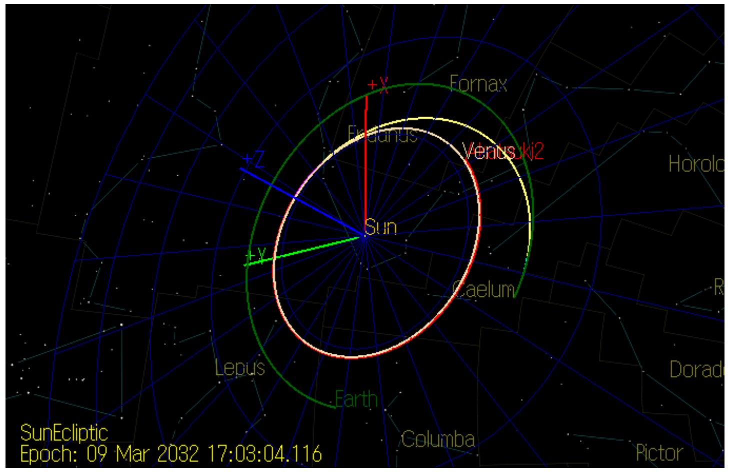
Venus L1 Lissajous orbit

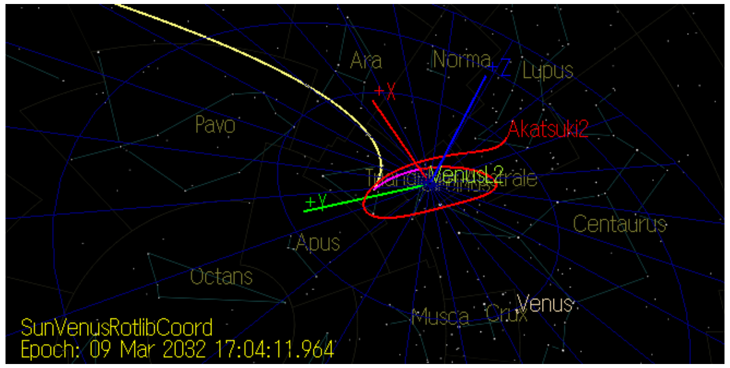
ΔVbL (1-6m/s) by RCS

Venus L2 Lissajous orbit

Attitude control by RCS (200m/s)

Probe Propulsion





Station keeping in L1/L2 Lissajous orbit by RCS

ΔVsk (1-10 m/s /year)

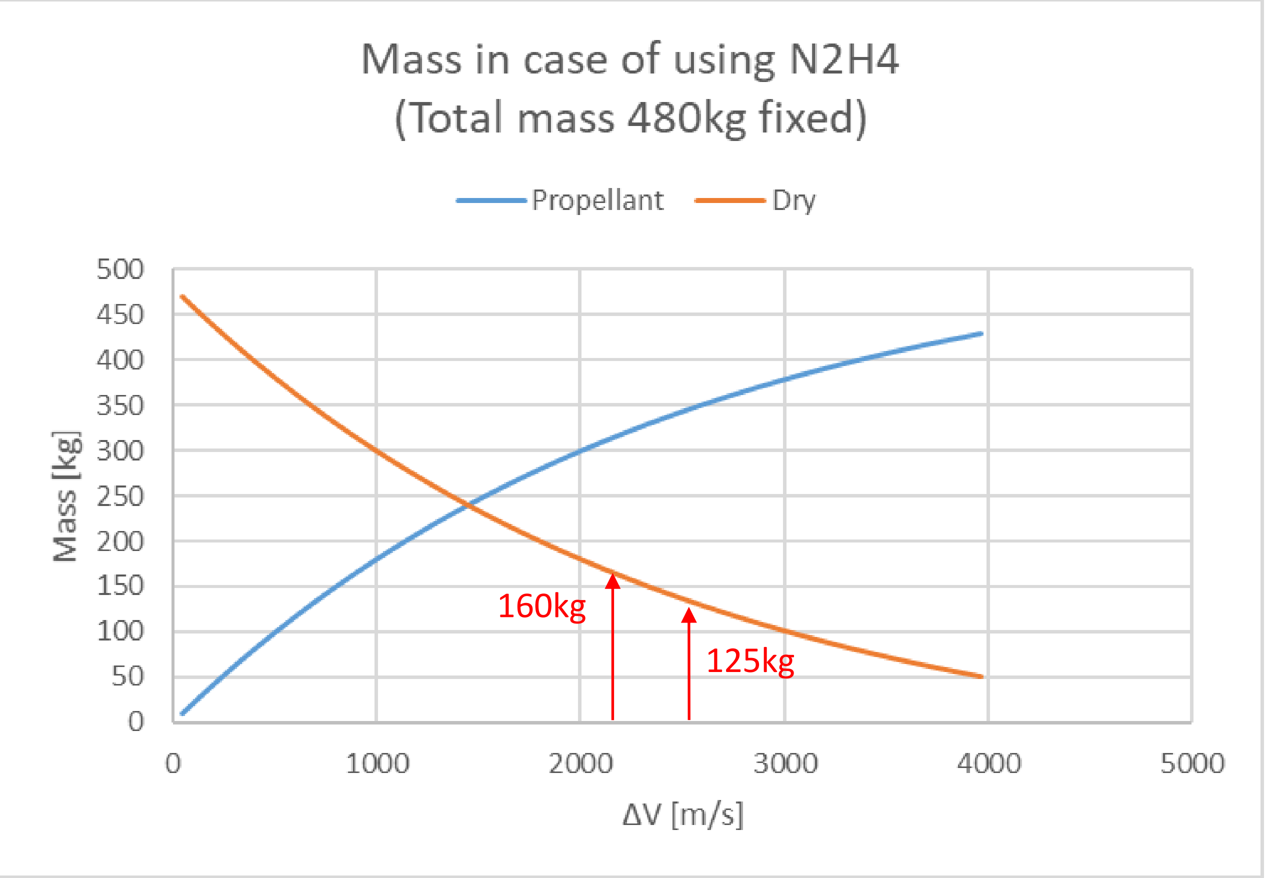
⇒ probe total mass = 480kg
ΔV = 2500～2800 m/s
(ΔV by OMS = 2200～2600m/s)

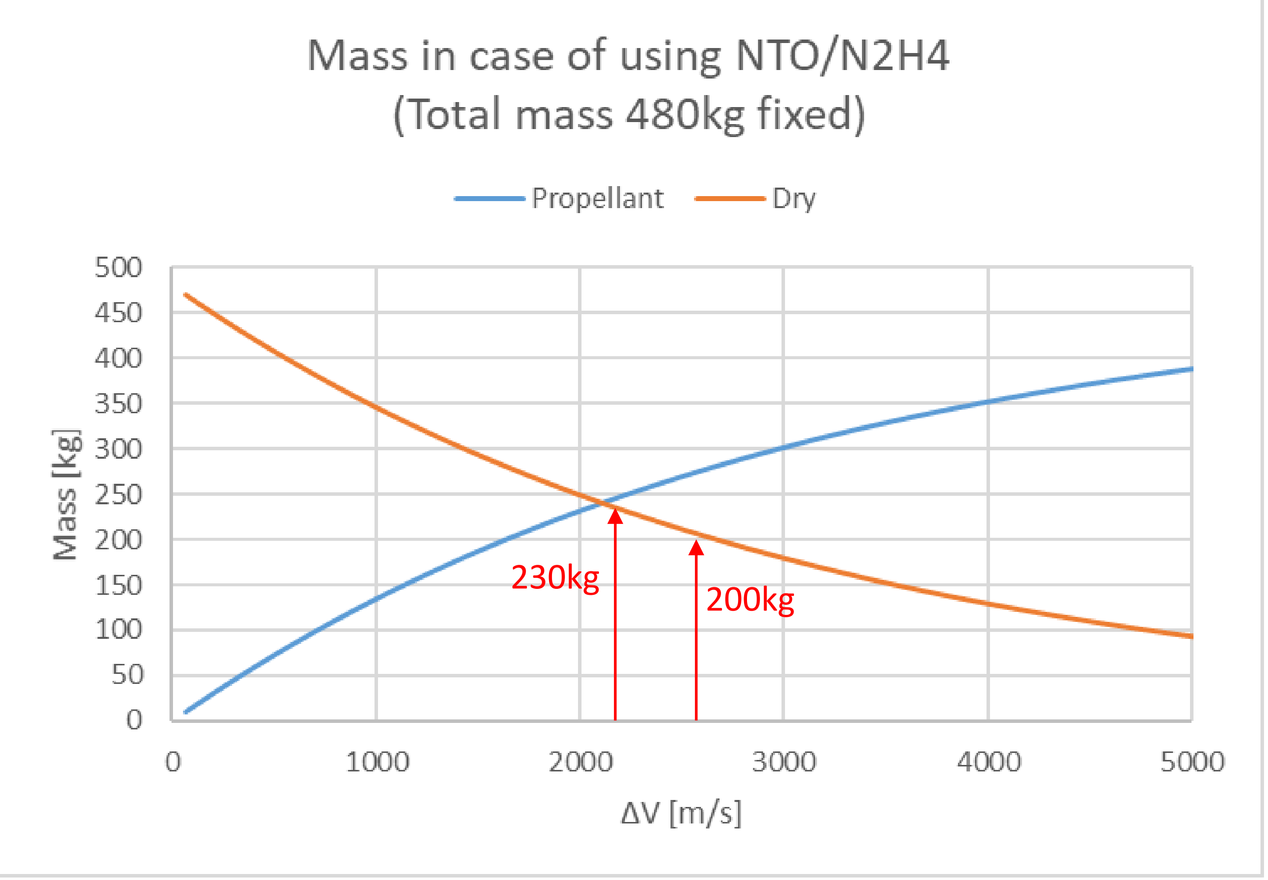
Propellant Selection for OMS

NTO/N2H4 is preferable for OMS Propellant in the range of ΔV 2200～2600m/s.
(see right figures)

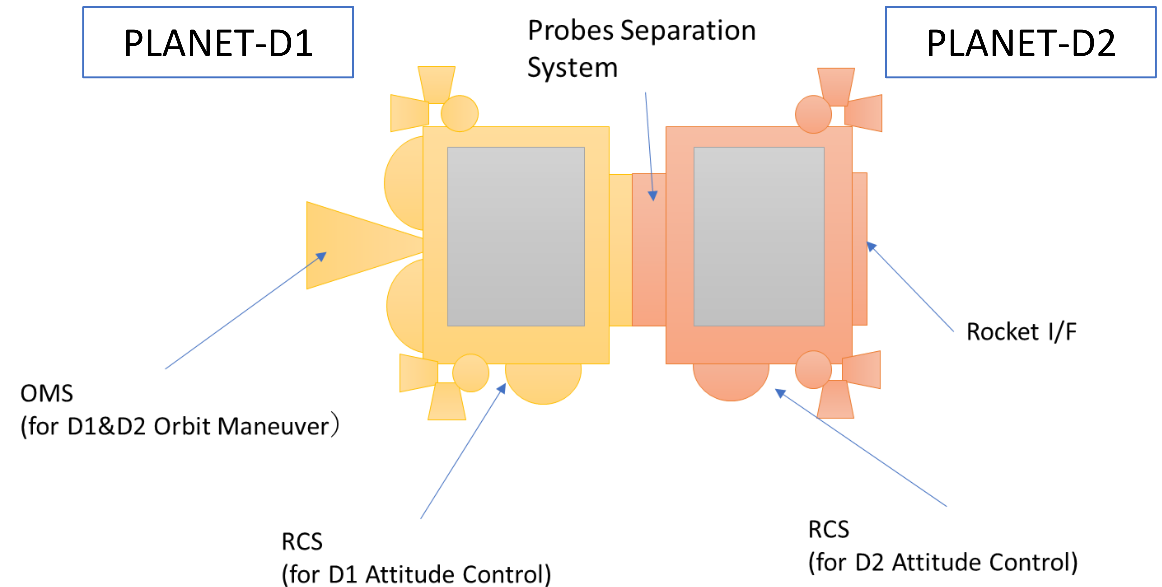
	N2H4		NTO/N2H4	
ΔV [m/s]	2200	2600	2200	2600
Propellant Mass [kg]	320	355	250	280
Dry Mass [kg]	160	125	230	200
Sum [kg]	480	480	480	480

*Dry mass in this page means the mass except OMS propellant





Mass Distribution



Mass distribution based on NTO/N2H4 OMS system is as below.

Contents		Mass [kg]		notes
		for OMC ΔV =2200 m/s	for OMC ΔV =2600 m/s	
D1	Mission devices	16	16	LIR, UVI, LAC, PIM
	Bus Structure/devices	30*	30*	Power, Communication, A/O control
	Propulsion devices	91	99	OMS, RCS
	Propellant	294	324	NTO,N2H4
D1 Sum		430	469*	
D2	Mission devices	26	26	LIR, IR2, LAC, PIM
	Bus Structure/devices	15*	15*	Power, Communication, A/O control
	Probes Separation System	1	1	
	Rocket I/F	1	1	
	Propulsion devices	5	5	RCS
	Propellant	2	2	N2H4
D2 Sum		50	50	
D1 + D2 Sum		480	519*	Launch capacity is 480kg

*necessary to improve

Current Issues

1. ΔV optimization
   - Acceleration timing
   - Swing-by
   - Tolerance to Z-direction amplitude in Lissajous orbit

2. Mass distribution
   - Refinement of bus structure/devices
   - Updating of devices information
   - Redistribution of D1/D2 function

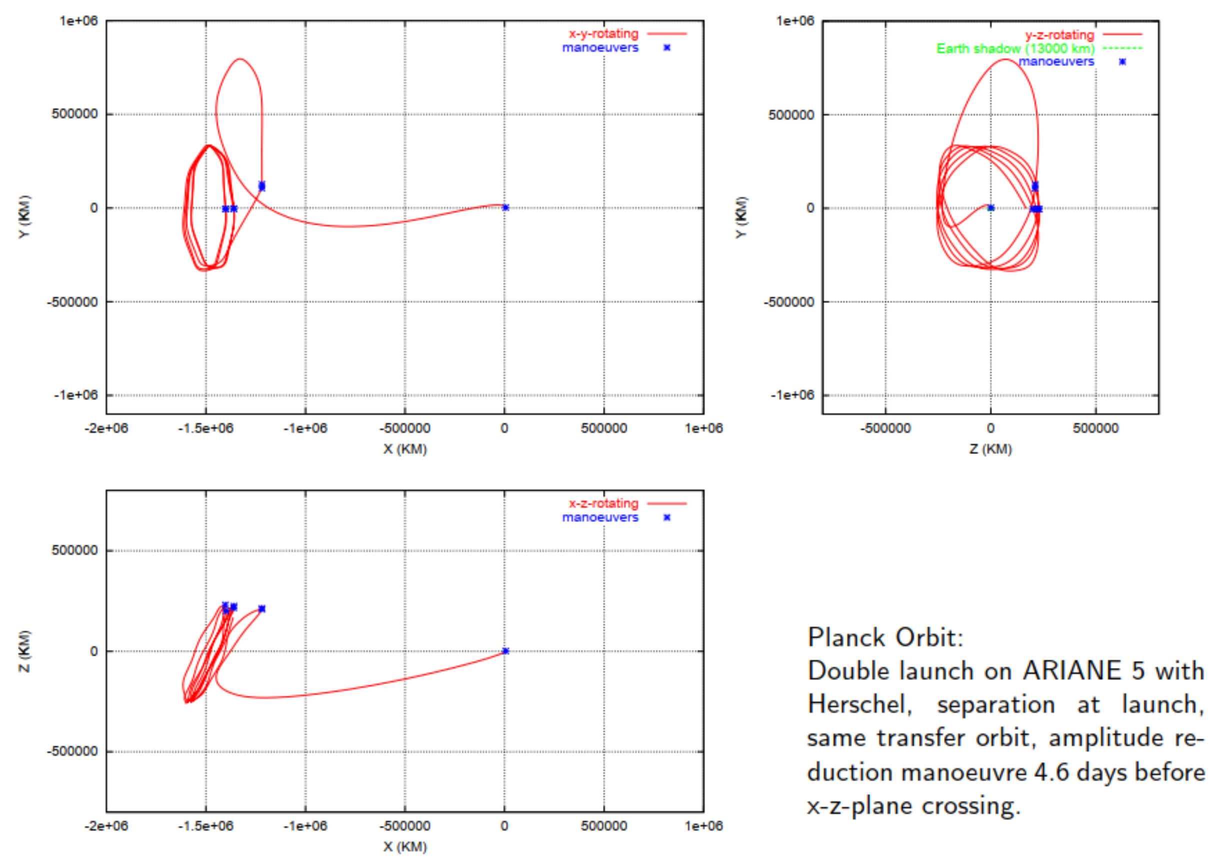
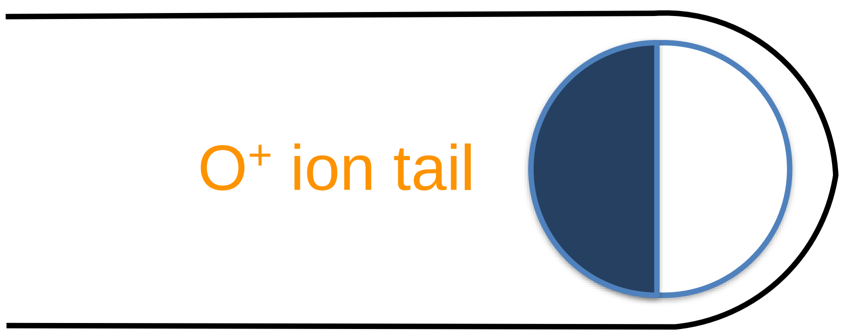


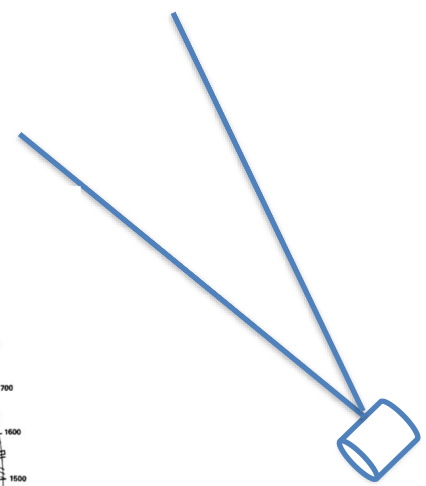
Figure 5: *Numerical construction of Planck orbit*

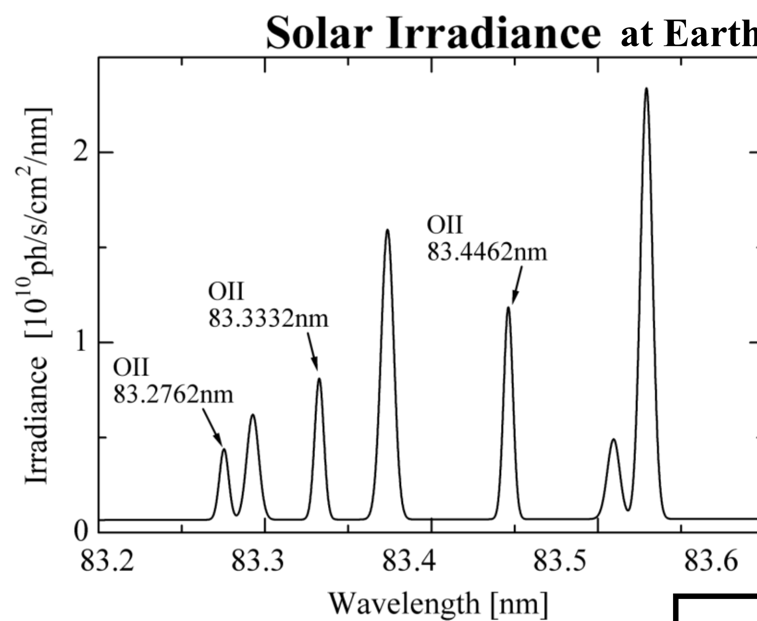
Image by the paper: Optimization for Lissajous Orbit

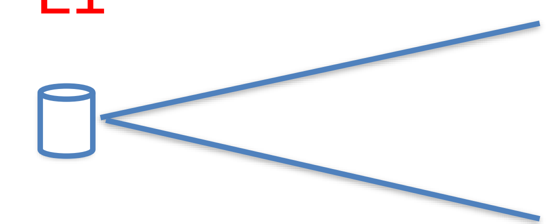
Optional Instruments for ion escape



EUV imager







- Solar EUV monitor
- Fluxgate magnetometer

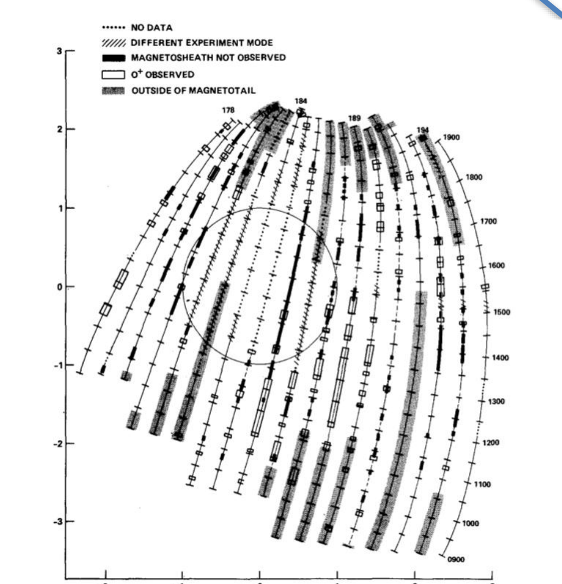
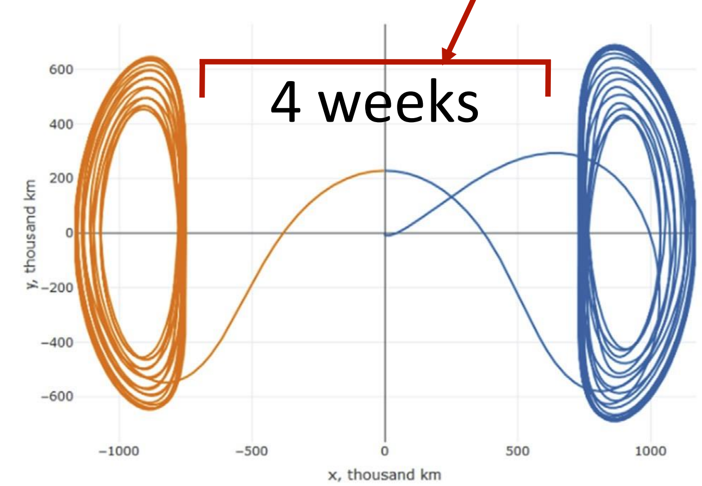
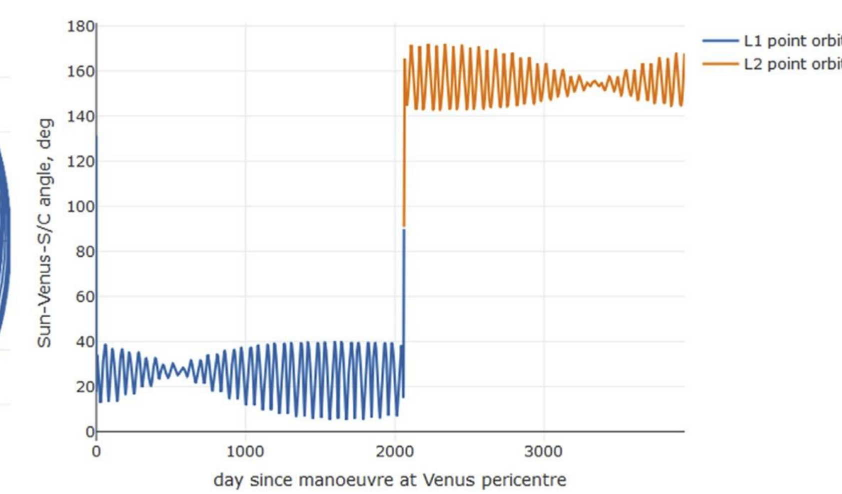


Fig. 44. Projections of Pioneer Venus nightside apoapsis Orbit segments on the terminator plane showing where the plasma analyzer observed the wake ion plasma cavity (black bars) and picked up O^+ (white bars) near $\sim 12\ R_v$ (from Mihalov and Barnes, 1981). The oxygen appears in the energy/charge spectra as in Figure 22.

O^+ distribution observed by PVO [Luhmann, 1986]

Observation can be done during L1 to L2 transfer





Summary

- We need to plan a new generation Venus mission after Akatsuki.
- Russia is planning Venera-D in 2029 and Lagrange point mission
  (India plans something)
- ISAS has a heritage of Akatsuki 5 cameras and easy to put them to the new mission, Planet-D.
- Planet-D consists of two spacecraft inserted into Lagrange points, L1 and L2 and look at the dayside and nightside hemisphere. UVI, LIR and IR2 are the candidate cameras onboard the spacecraft.
- Launch by Epsilon launch vehicle is assumed.
- Ion escape may be imaged during one spacecraft's moving from L1 to L2.