Libration Point and Lunar Swingby Trajectories

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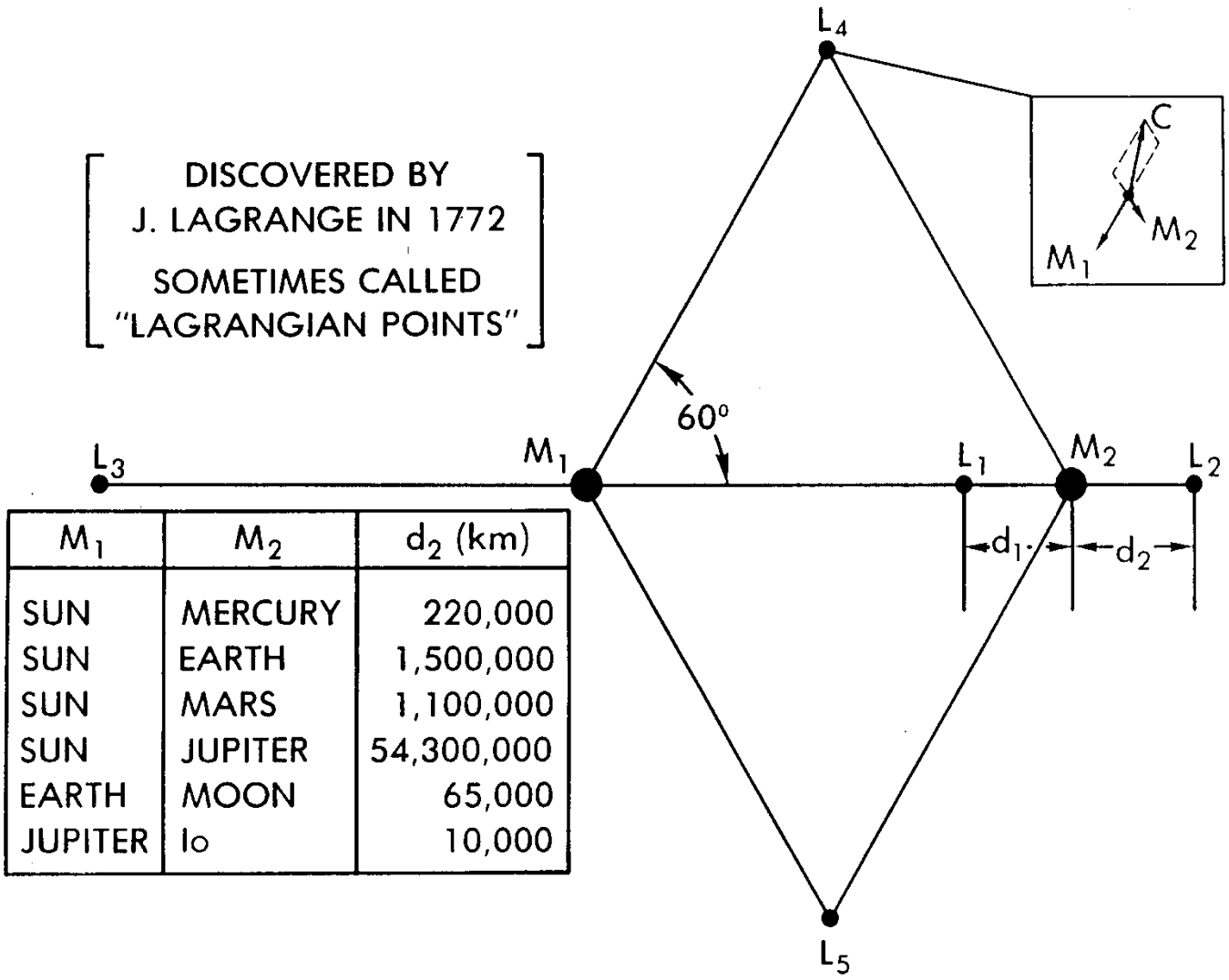
Libration Point and Lunar Swingby Trajectories

- These trajectories enable space telescope servicing either by transporting repair team to the telescope or the telescope to elliptic Earth orbit
- Mission options exist for Ares V to use libration point and lunar swingby trajectories to extend exploration beyond the Moon
  - Extended/Modified use of planned vehicles
  - Low-cost, low-risk incremental approach to extending human exploration
  - SEL2 → NEA → Phobos → Mars
- Assumptions:
  - Large space telescopes at SEL2 will require servicing
  - Human space exploration will continue
  - NASA will develop
    - Crew exploration vehicle (Orion)
    - Crew launch vehicle (Ares-1)
- Factors used to compare alternatives
  - Science value
  - Cost effectiveness
  - Mission risk
  - Flexibility
  - Sustainability
  - Extension to other exploration destinations

Libration Points

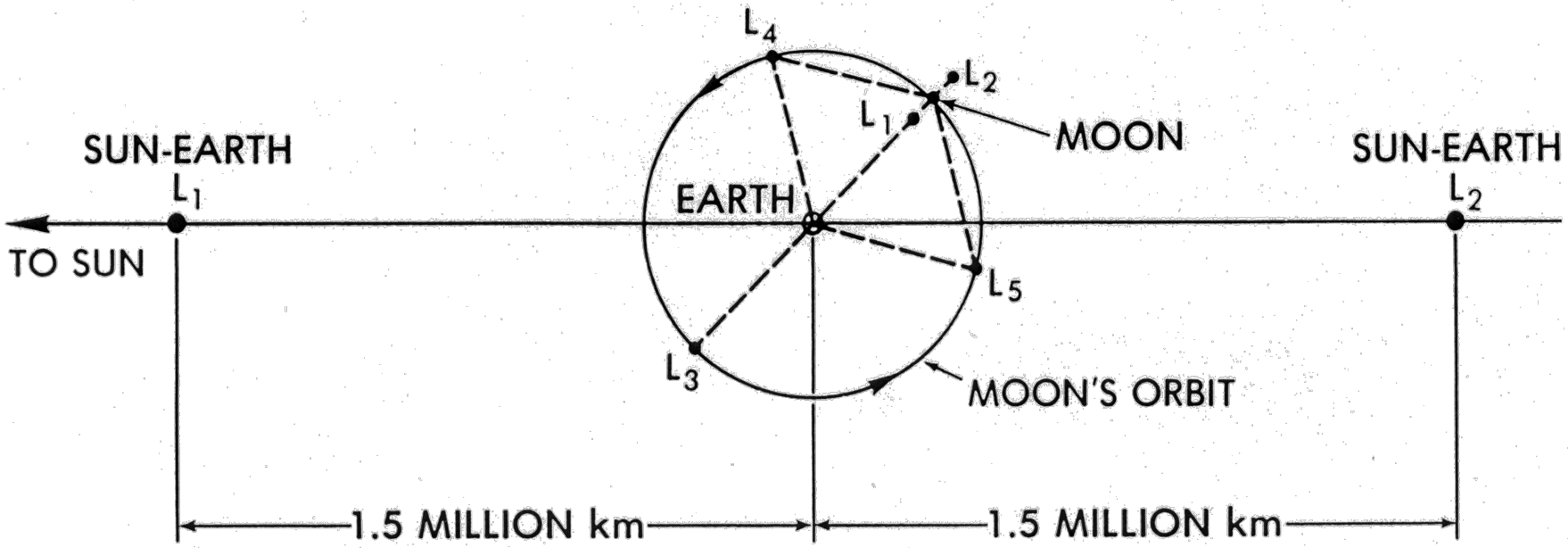
DISCOVERED BY
J. LAGRANGE IN 1772

SOMETIMES CALLED
"LAGRANGIAN POINTS"

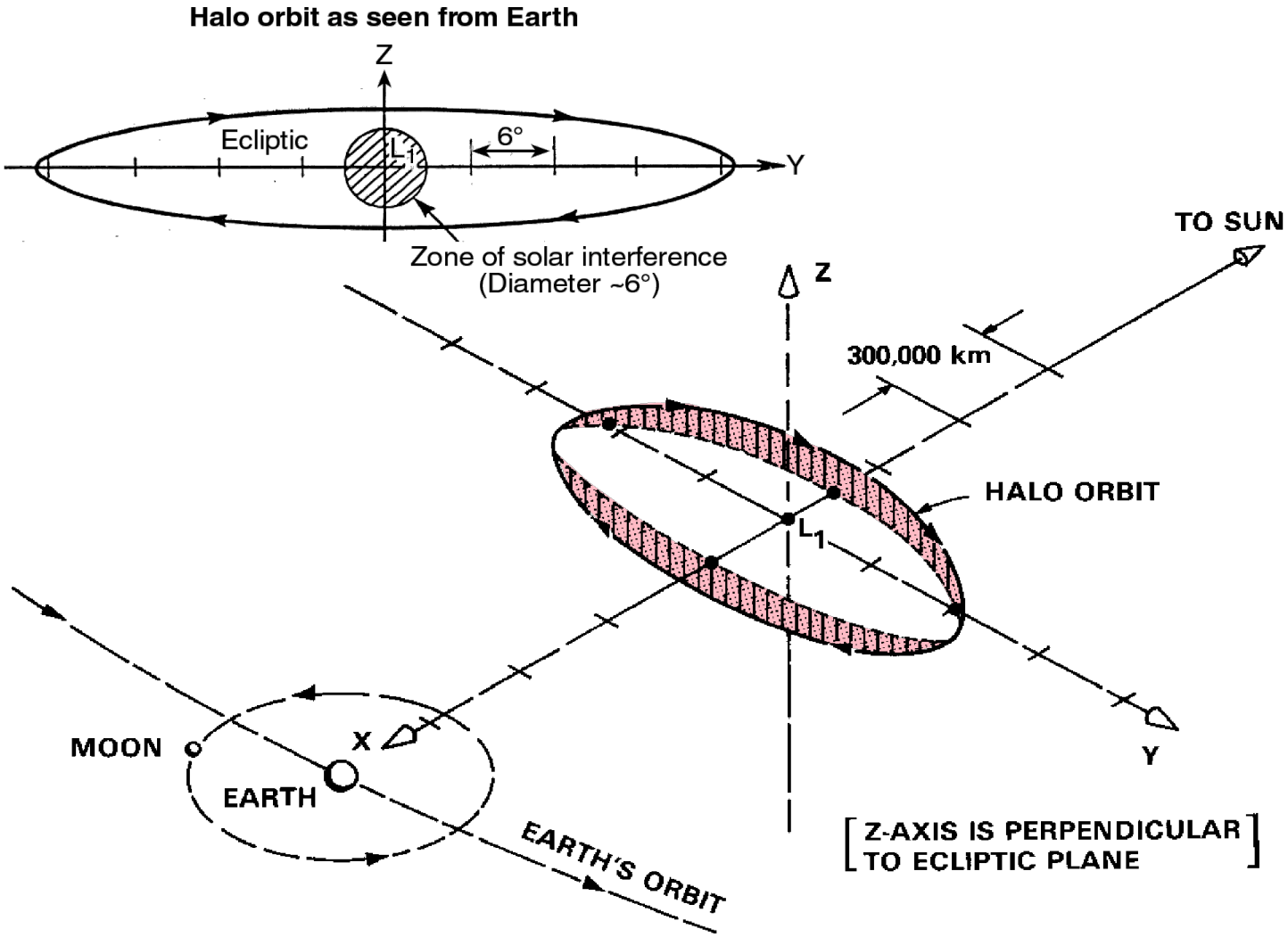


M_1	M_2	d_2 (km)
SUN	MERCURY	220,000
SUN	EARTH	1,500,000
SUN	MARS	1,100,000
SUN	JUPITER	54,300,000
EARTH	MOON	65,000
JUPITER	Io	10,000

Libration Points in the Vicinity of the Earth



Halo Orbit Around the Sun–Earth L1 Libration Point



Trajectories to the Sun-Earth L1 Libration Point

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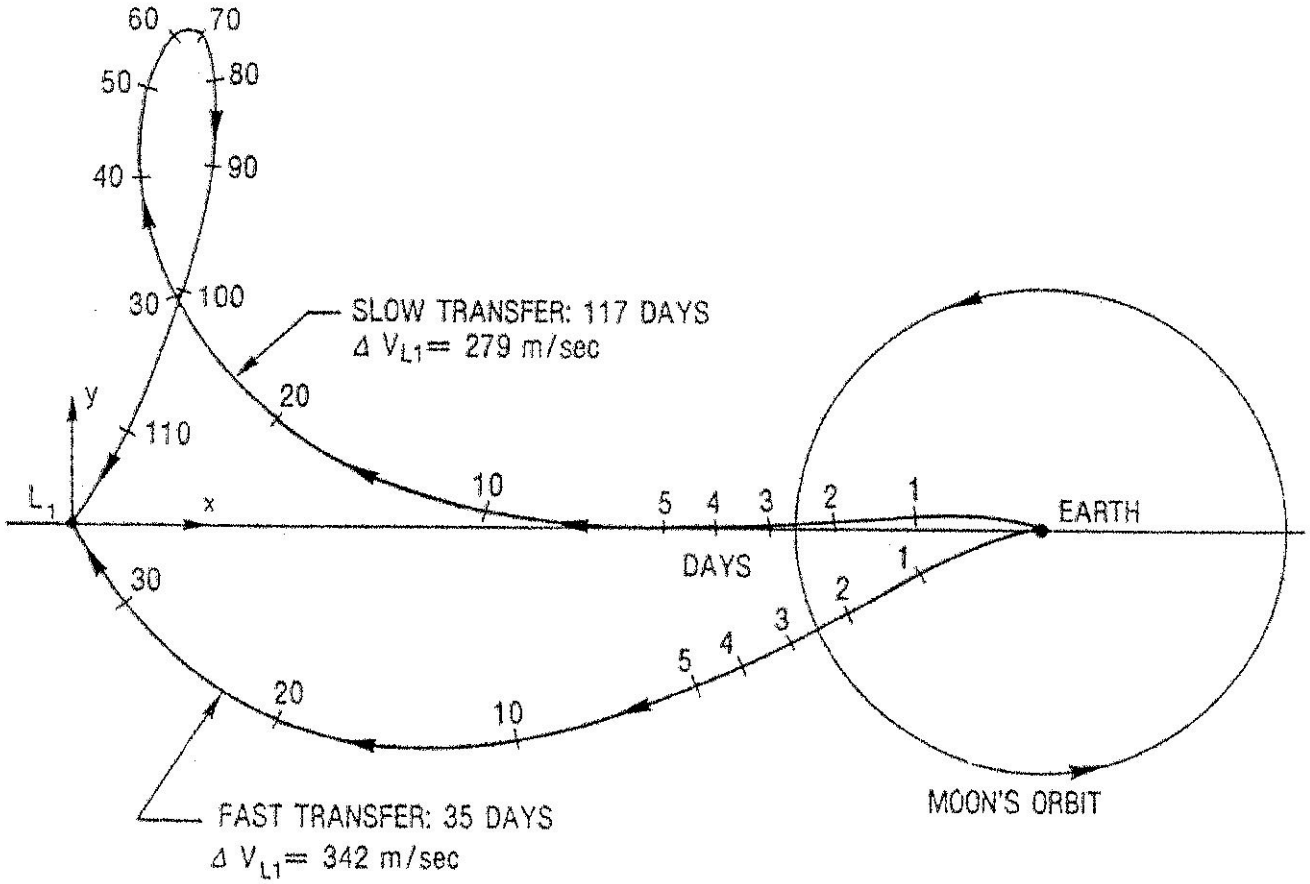
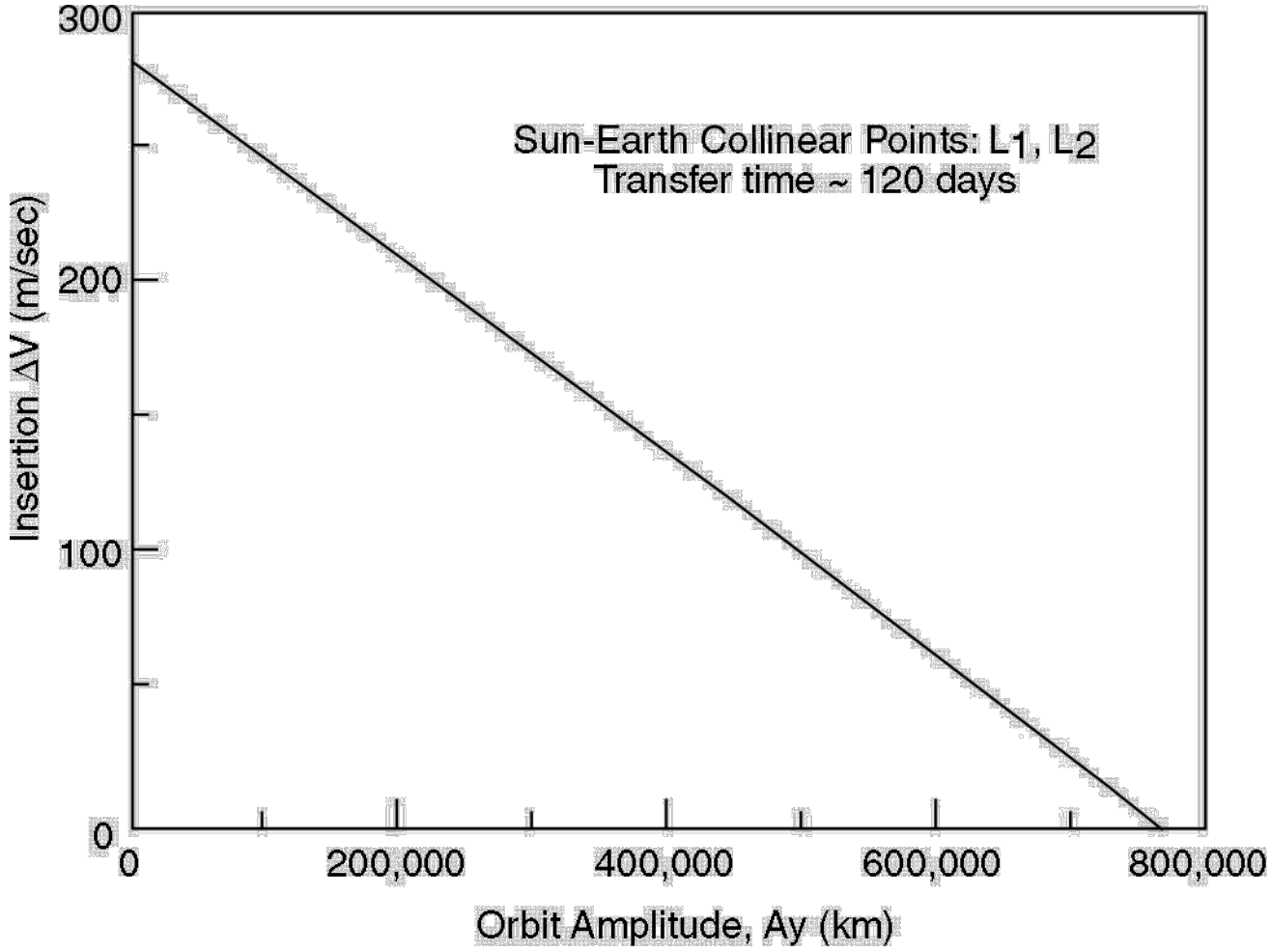
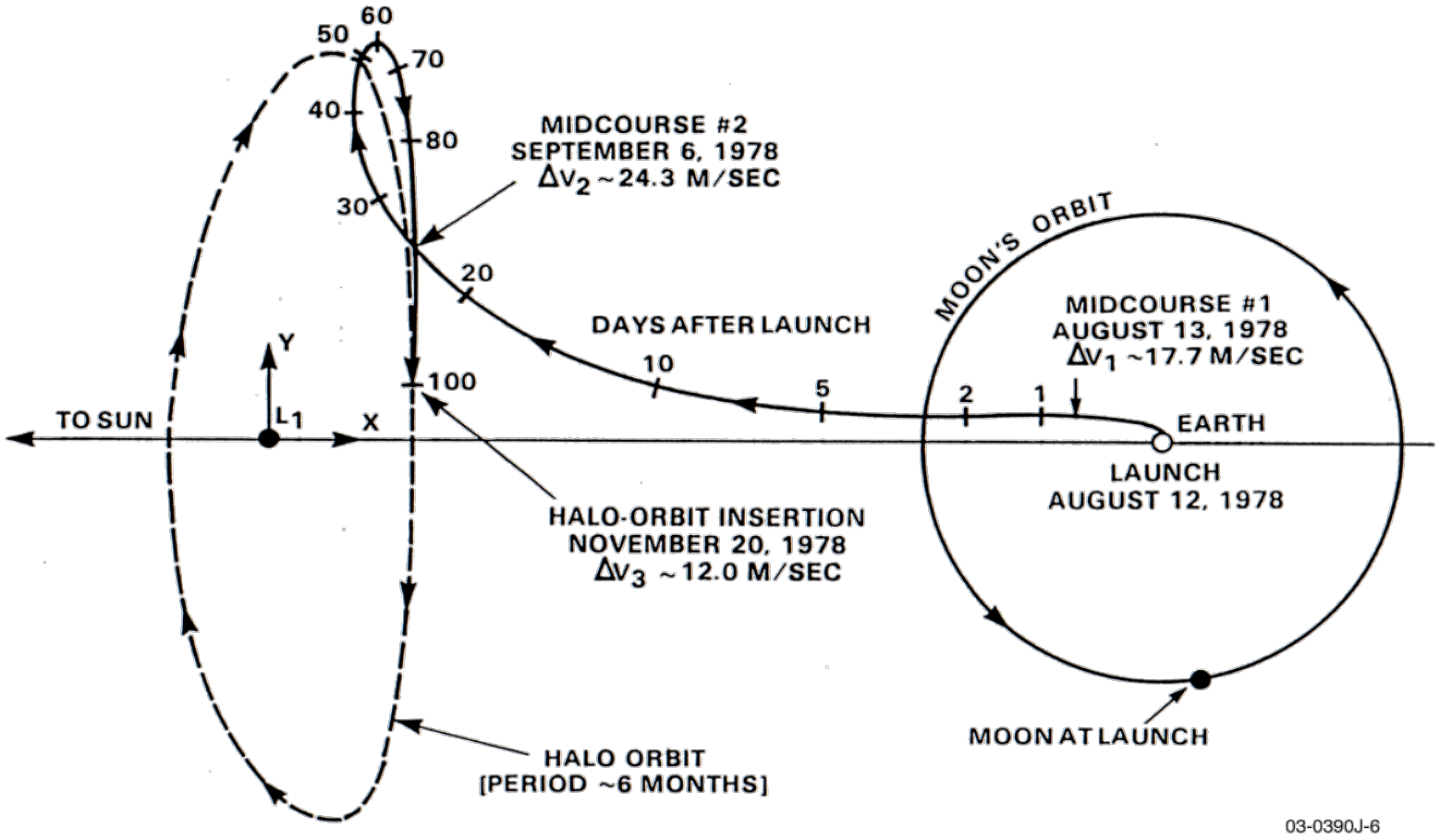


ΔV Cost for Slow Transfers to Sun–Earth Halo Orbits



ISEE-3 Slow Transfer Trajectory to Halo Orbit

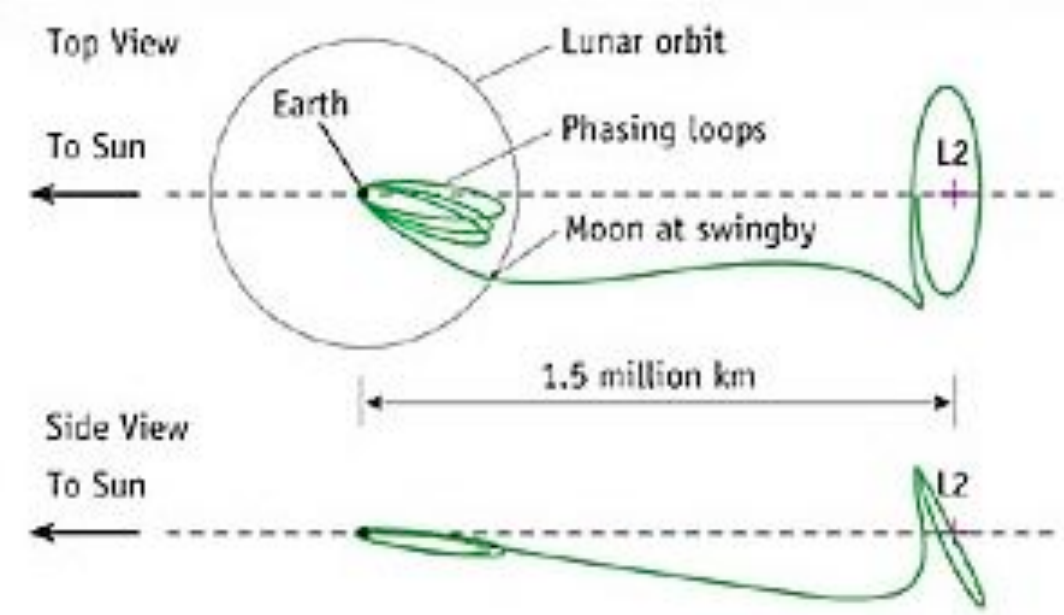


Libration-Point Missions

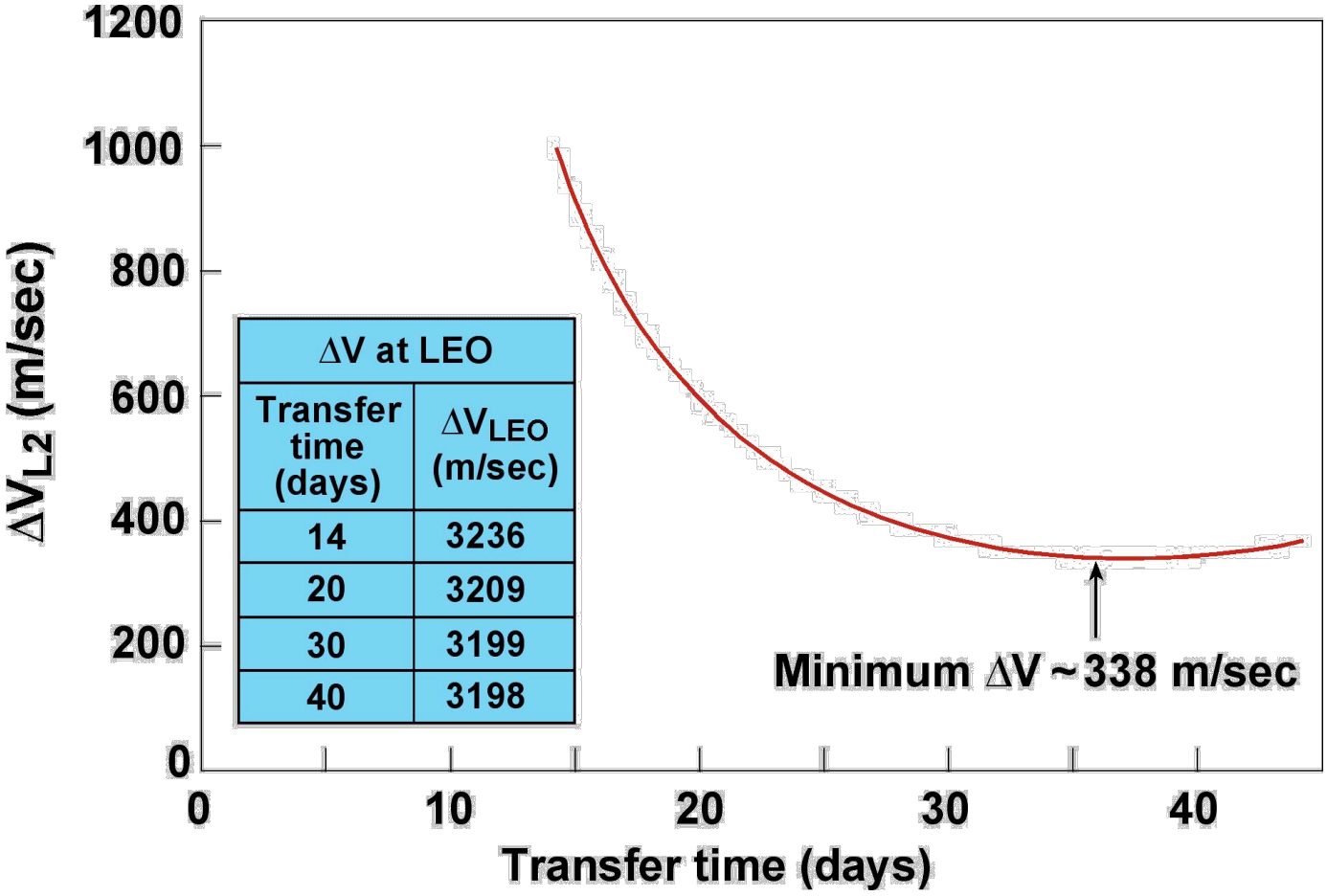
Mission*	Sun-Earth Libration Point	Date of Orbit Insertion	Mission Purpose
ISEE-3 [NASA]	L1, L2	1978, 1983	Solar wind, cosmic rays, plasma studies
WIND [NASA]	L1	1995, 1997	Solar wind monitor
SOHO [ESA/NASA]	L1	1996	Solar observatory
ACE [NASA]	L1	1997	Solar wind, energetic particles
WMAP [NASA]	L2	2001	Cosmic microwave background
Genesis [NASA]	L1	2001	Solar wind composition
Herschel [ESA]	L2	2008	Far-infrared telescope
Planck [ESA]	L2	2008	Cosmic microwave background
GAIA [ESA]	L2	2012	Galactic structure, astrometry
JWST [NASA]	L2	2013	Deep space observatory
XEUS [ESA]	L2	2015	X-ray spectroscopy
Darwin [ESA]	L2	2015	Infrared space interferometry
Constellation-X [NASA]	L2	?	X-ray astronomy
TPF [NASA]	L2	?	Origin and evolution of planetary systems

*Acronyms:
ISEE (International Sun-Earth Explorer)
ACE (Advanced Composition Explorer)
GAIA (Global Astrometric Interferometer for Astrophysics)
SOHO (Solar and Heliospheric Observatory)
WMAP (Wilkinson Microwave Anisotropy Probe)
JWST (James Webb Space Telescope)
TPF (Terrestrial Planet Finder)
XEUS (X-ray Evolving Universe Spectrometer)

WMAP used lunar swingby to achieve small-amplitude L_2 orbit



Fast Transfers: Low-Earth Orbit (LEO) to Sun–Earth L2 Point

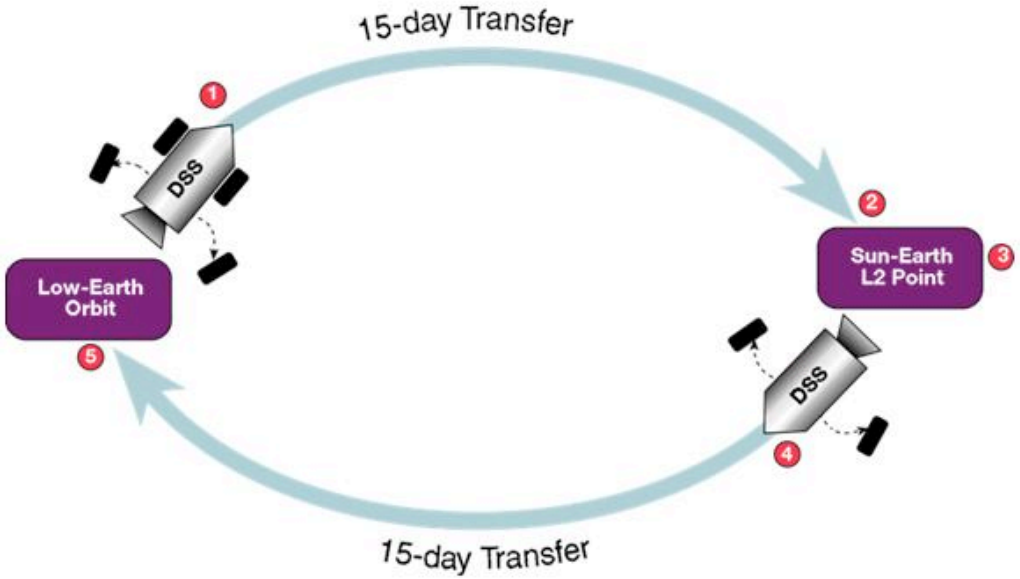


ΔV at LEO	
Transfer time (days)	ΔV_{LEO} (m/sec)
14	3236
20	3209
30	3199
40	3198

Approximate Round-Trip ΔV Requirements for Transfers

	Destinations		
	Sun-Earth L1 or L2 Point	**Low-Lunar Orbit**	**Geosynchronous Orbit (without plane change)**
Round-trip flight time (does not include stay time at destination)	30 days	7 days	~11 hours
	ΔV Requirements (m/sec)		
LEO exit	3230	3150	2430
Destination entry	900	850	1470
Destination exit	900	850	1470
LEO entry (aerobrake)	–	–	–
Total	5030	4850	5370

Mission Scenario for Telescope Servicing at Sun–Earth L2 Libration Point



(1) Deep-Space Shuttle (DSS) leaves low-Earth orbit ($\Delta V \sim 3230$ m/sec). First set of drop tanks discarded. (Alternative: use expendable high-performance kick stage for injection into L_2 transfer orbit.)

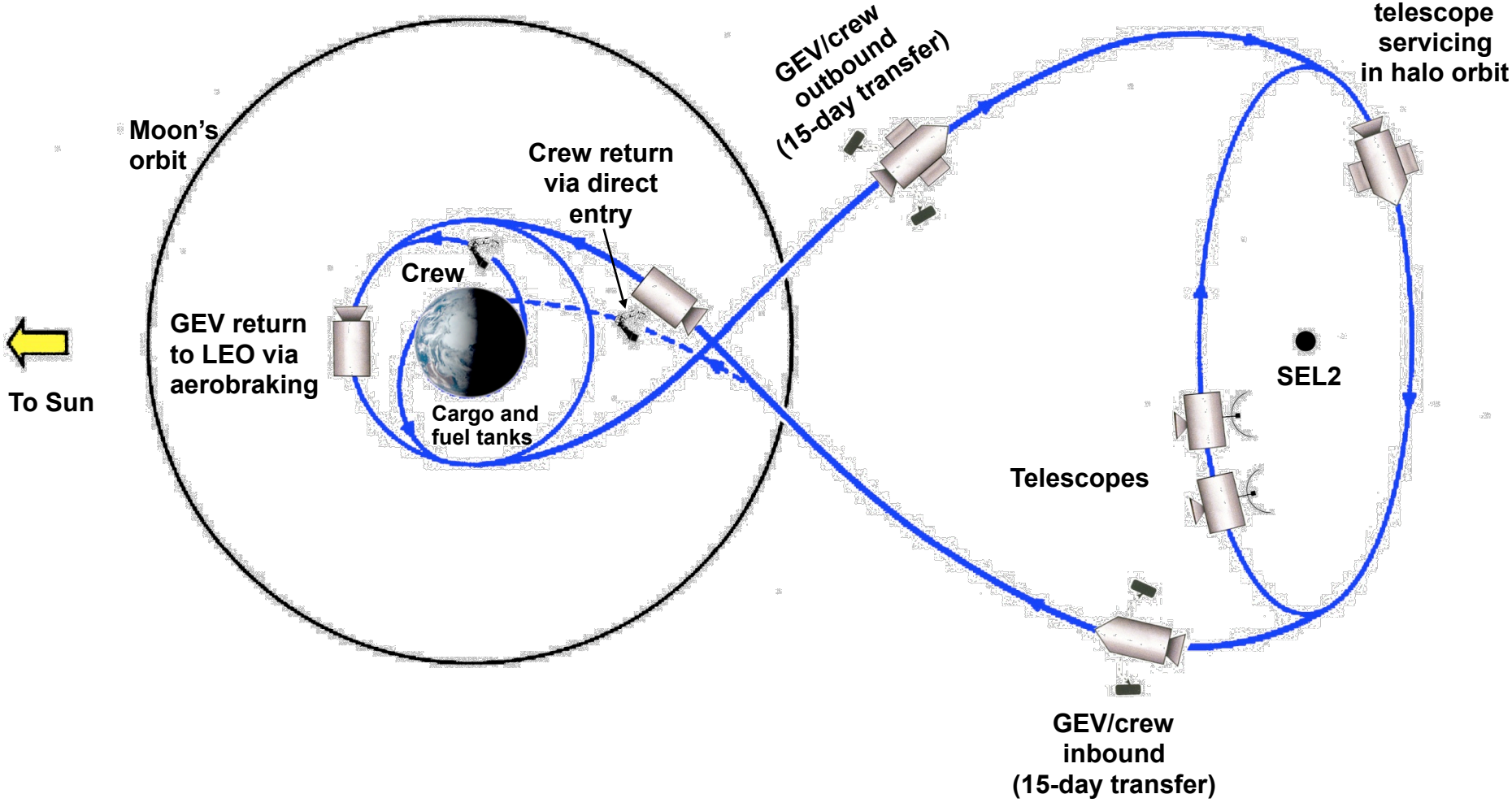
(2) DSS enters L_2 orbit ($\Delta V \sim 900$ m/sec).

(3) DSS services L_2 telescope (stay time ~5 days).

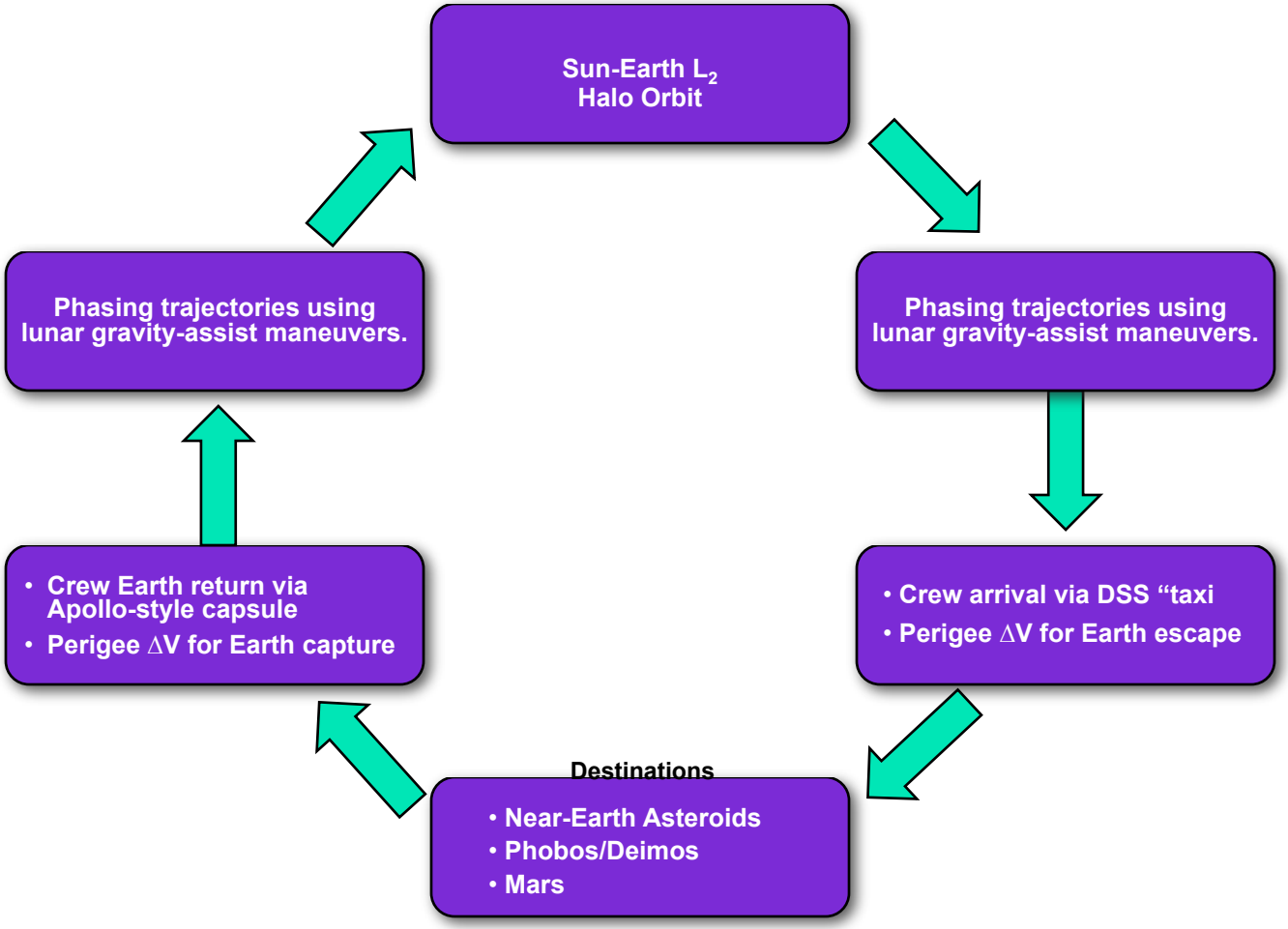
(4) DSS exits L_2 orbit ($\Delta V \sim 900$ m/sec). Second set of drop tanks discarded.

(5) Crew returns to Earth in Apollo-style capsule. DSS returns to low-Earth orbit using multiple aerobraking maneuvers.

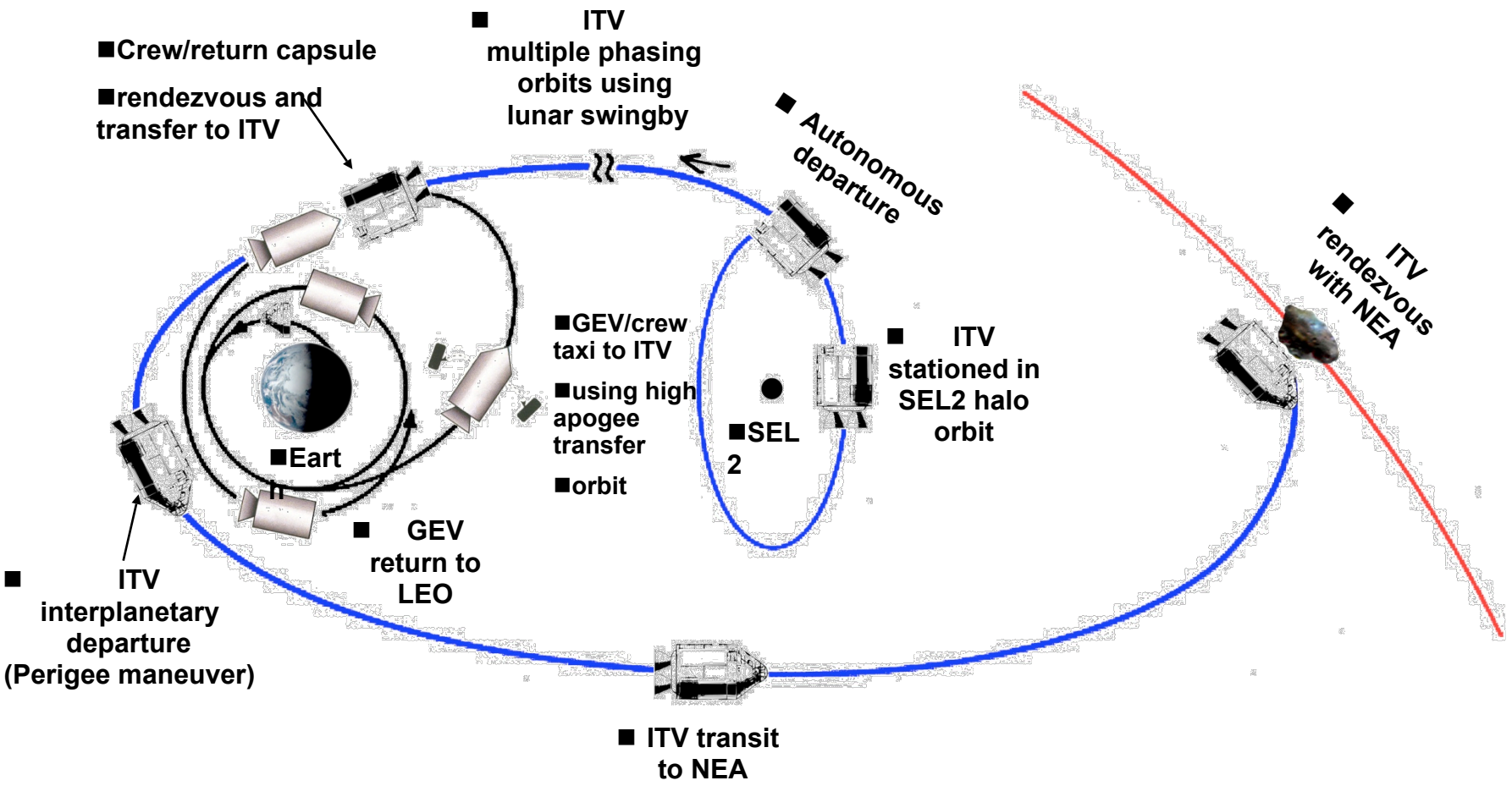
Sun-Earth L2 Mission Scenario



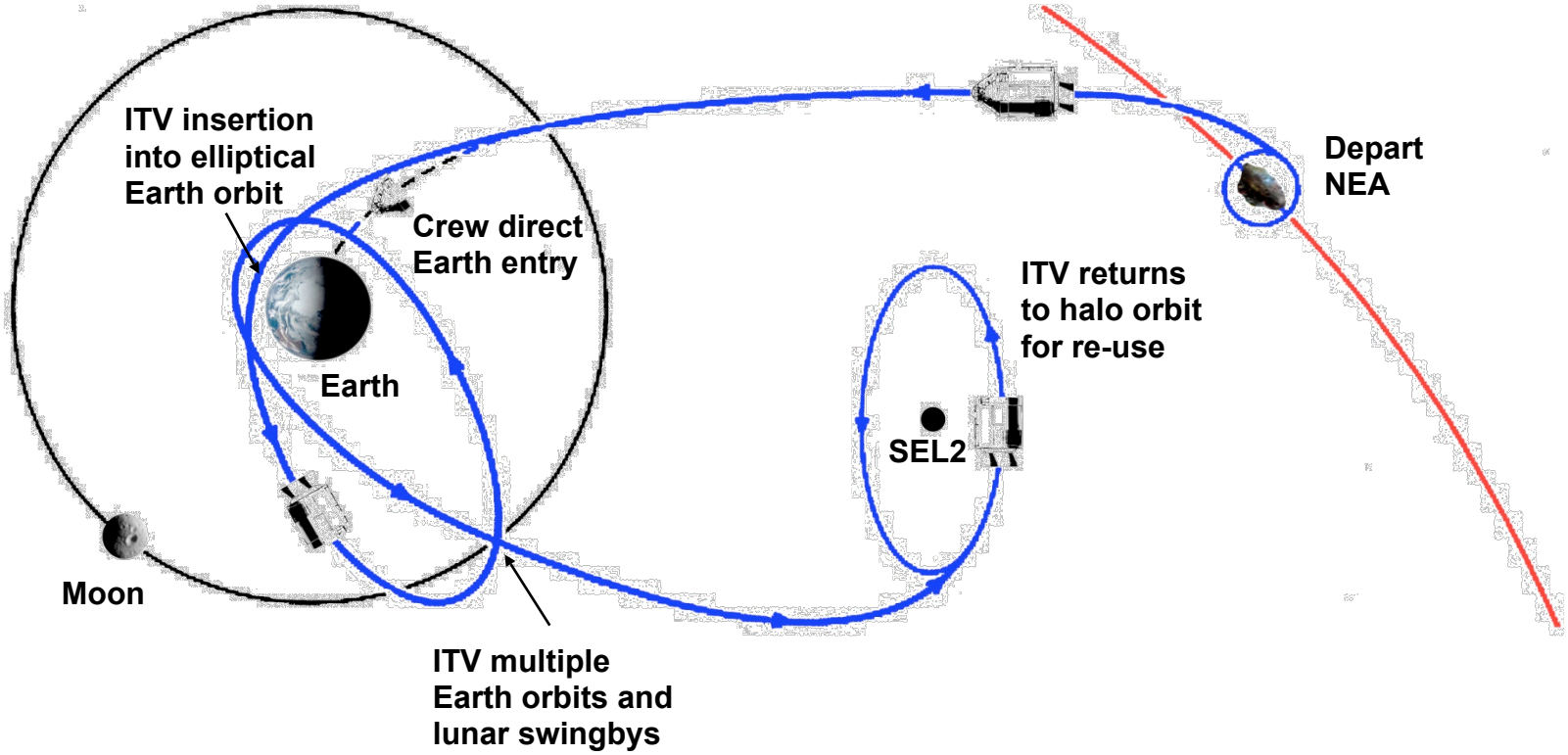
Interplanetary Transfer Vehicle Mission Scenario



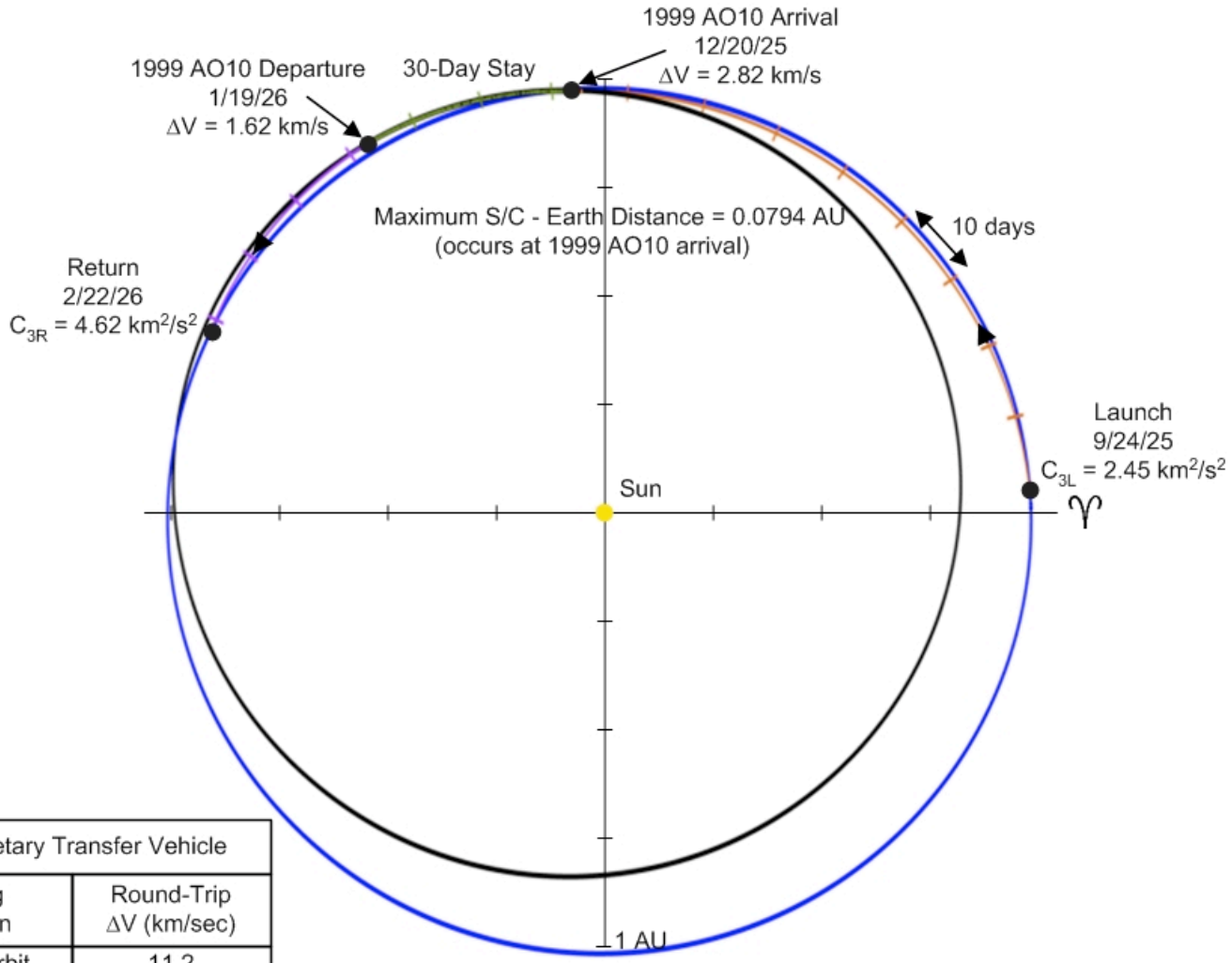
ITV Mission Concept-1



ITV Mission Concept-2

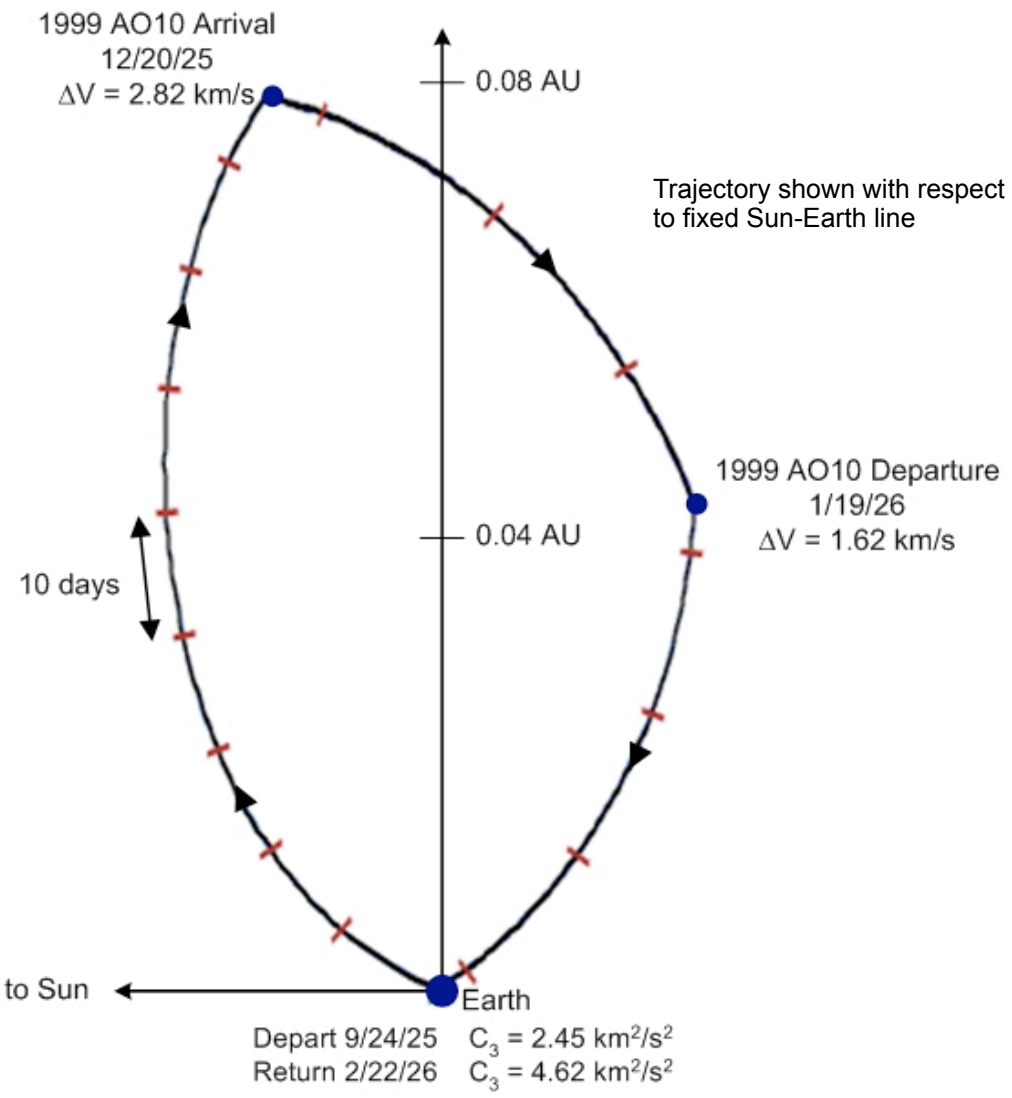


Five-Month Mission to Near-Earth Asteroid



Interplanetary Transfer Vehicle	
Staging Location	Round-Trip ΔV (km/sec)
Low Earth Orbit	11.2
Sun-Earth L_2 point	4.9

Five-Month Mission to Near-Earth Asteroid



Summary

- Delta-V cost for lunar, geosynchronous, SEL2 missions are similar
- Use low-cost, low-risk, incremental approach
- Develop Deep Space Shuttle (DSS)
  - Geosynchronous orbit (2 days)
  - Lunar orbit (10 days)
  - SE-L2 (30 days)
  - Enables space telescope servicing
- Develop Interplanetary Transfer Vehicle (ITV)
  - Near-Earth Asteroid
  - Phobos/Deimos
  - Mars landing