Access to Mars from Earth-Moon Libration Point Orbits: Manifold and Direct Options

Suggested EML_2 module
Image: NASA

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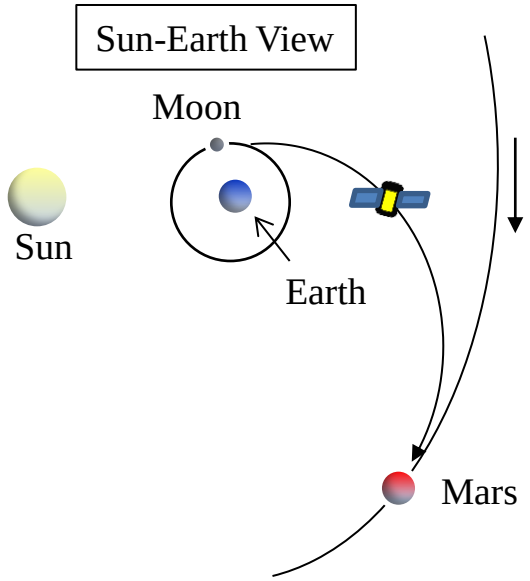
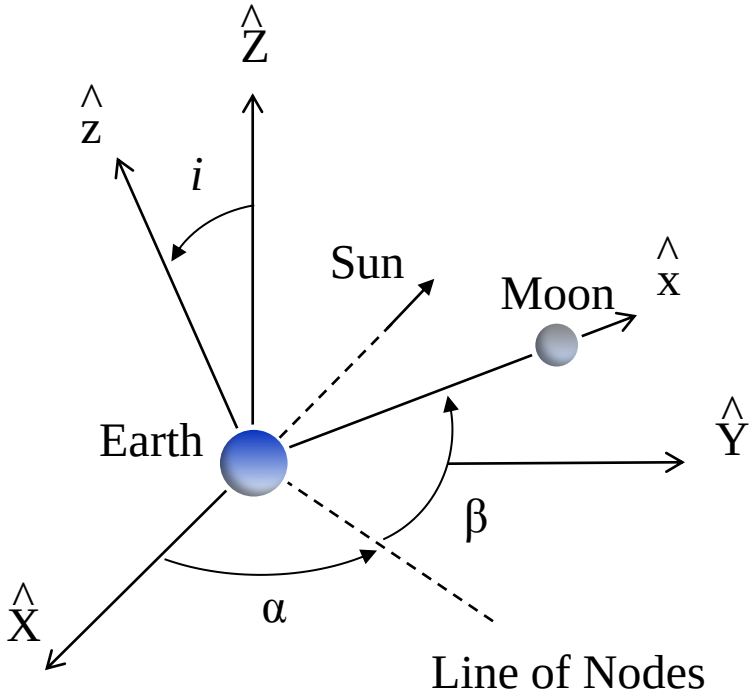
Objectives

Development of general procedure:

- Transfers from EM L_1/L_2 halo orbits to Mars
  - System model
  - EM manifold transfers
  - SE manifold transfers
  - Direct transfers
- Transition to higher fidelity model

System Model: Five-Body Problem

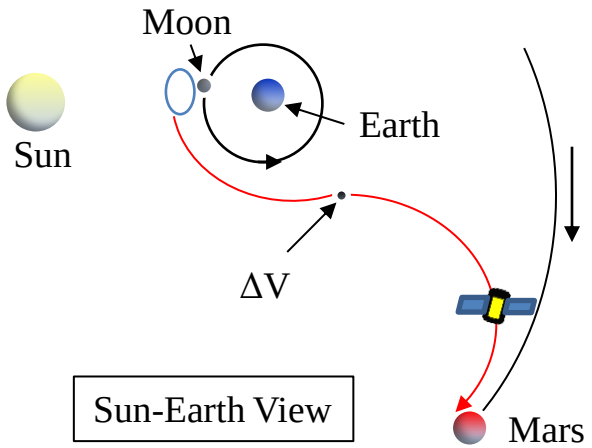




- Blended Sun-Earth-Moon model
  - Circular Restricted Three-Body Problems
  - Body two 3-1-3 Euler angle sequence
    - α : longitude of ascending node
    - i : inclination 5°
    - β : argument of latitude
- Mars: Ephemeris location

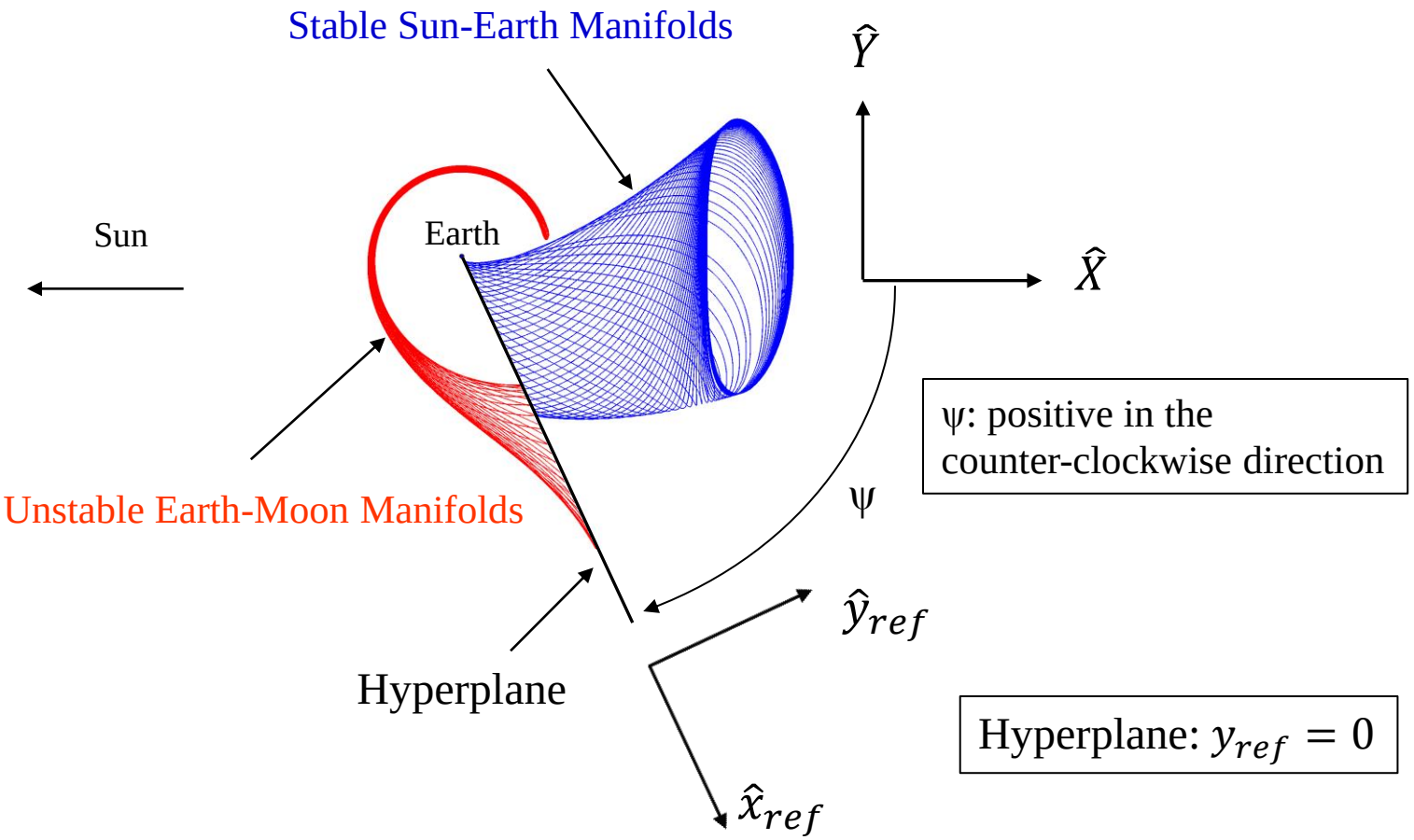
Scenario 1: Sun-Earth Manifold Transfers

- Scenario 1:
  - Earth-Moon halo orbit to Sun-Earth system
    - Manifold-to-manifold transfers
  - Sun-Earth system to Mars
    - Target ephemeris Mars



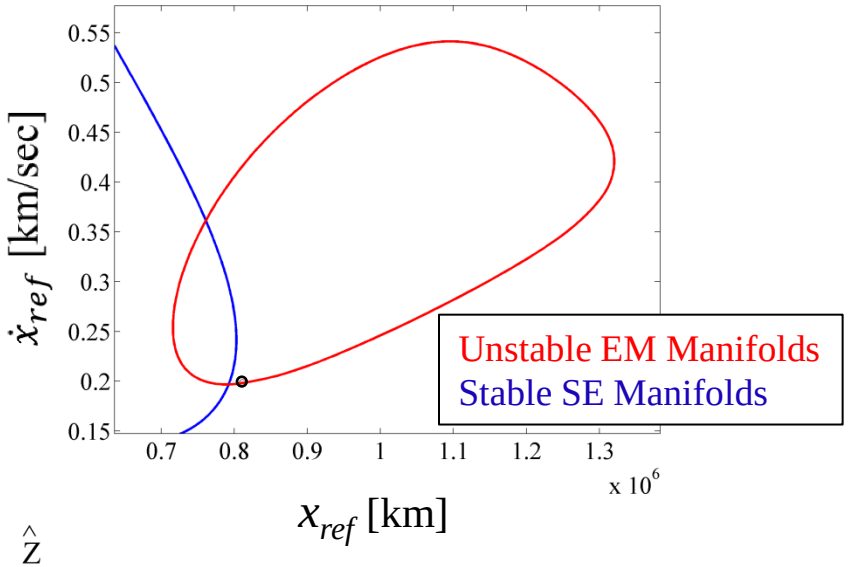
- Requirements:
  - Construct manifold-to-manifold transfer scheme
  - Construct Mars targeting scheme

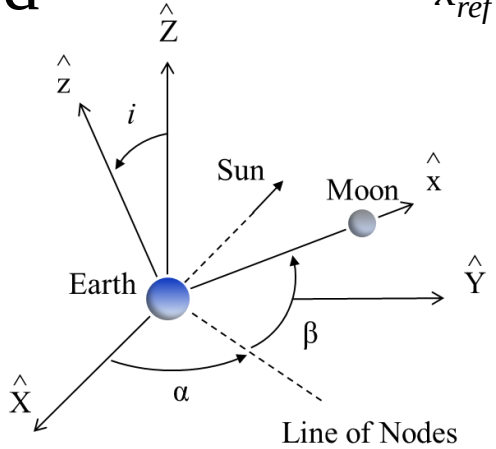
Defining Reference Frame

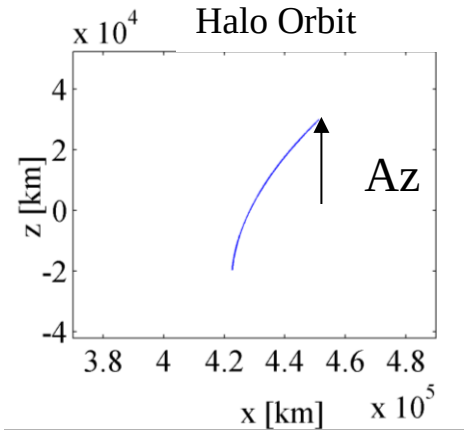


Phase Plots

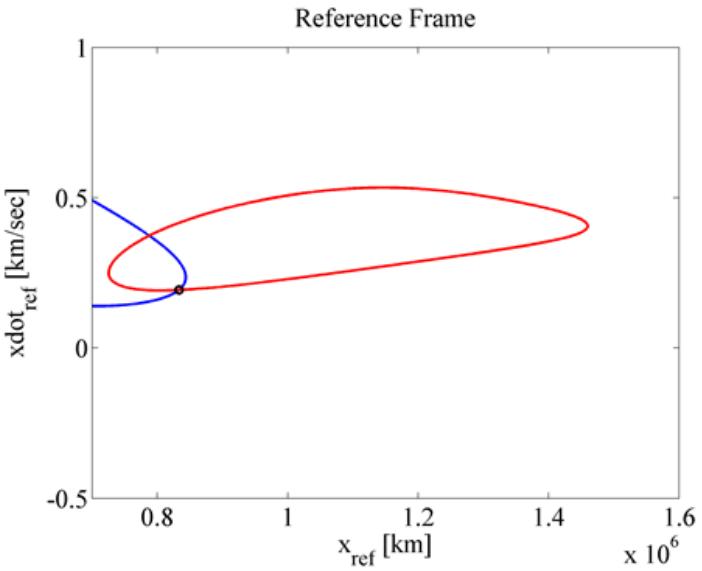
- Three phase plots
  - $\dot{x}_{ref}$ vs x_{ref}
  - z_{ref} vs x_{ref}
  - $\dot{z}_{ref}$ vs z_{ref}
  - Fix $\dot{x}_{ref}, x_{ref}, z_{ref}, \dot{z}_{ref}$
- 5 components fixed
- Jacobi constant
  - Fix $\dot{y}_{ref}$
- Parameters
  - α, β, ψ, EMAz, SEAz

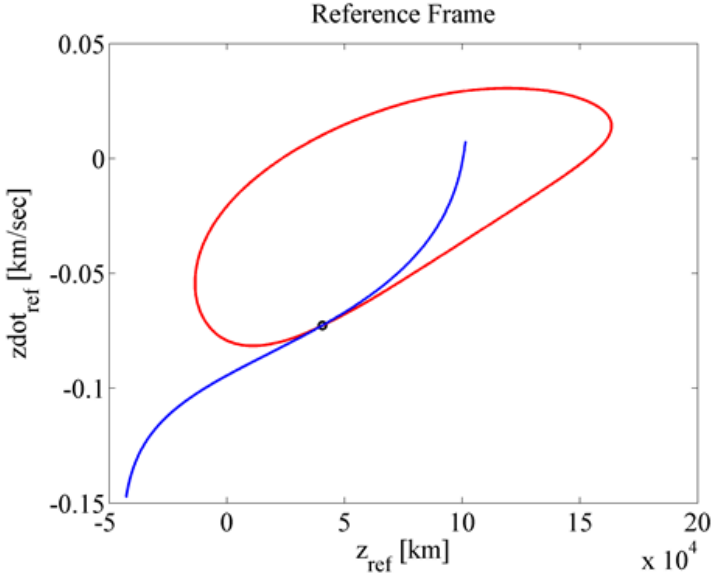


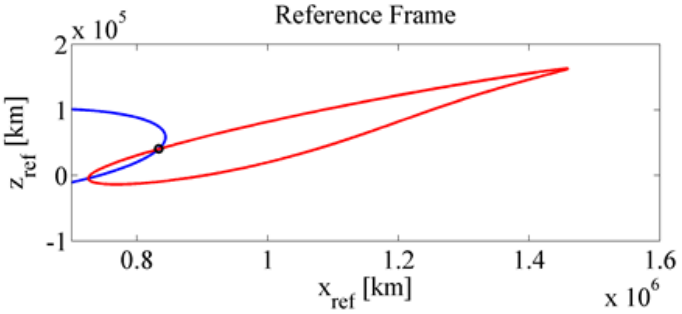




Phase Plots: α, β, ψ, EMAz, SEAz Corrected



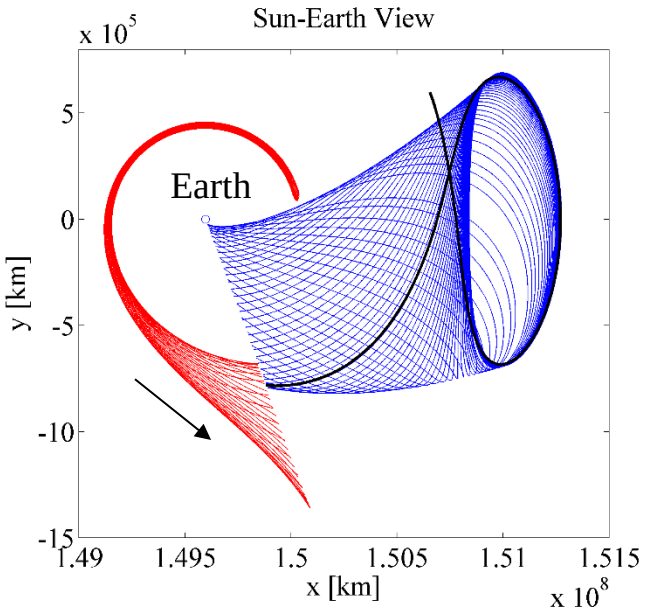


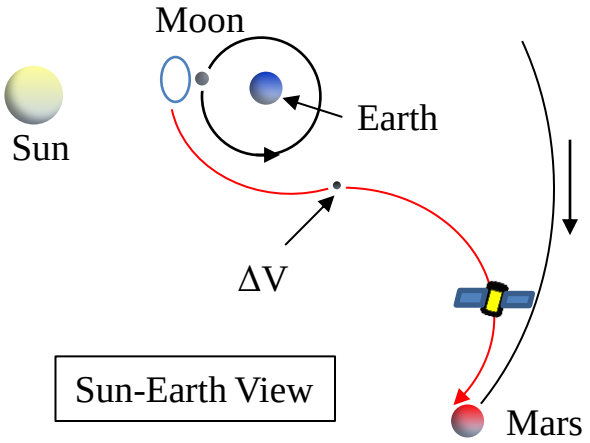


- Maneuver-free manifold-to-manifold transfers computed
  - Red curves and blue curves
    - Intersect at black circle
- Applicable to transfers between EML_2 and SEL_1/L_2

Scenario 1: Sun-Earth Manifold Transfers

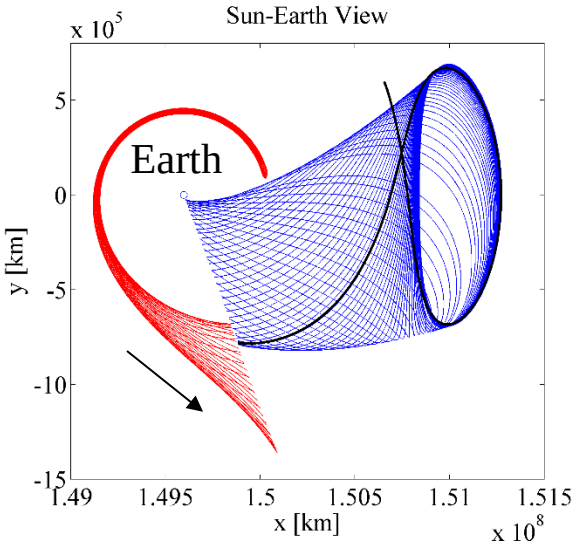
- Requirements:
  - Construct manifold-to-manifold transfer scheme ✓
  - Construct Mars targeting scheme



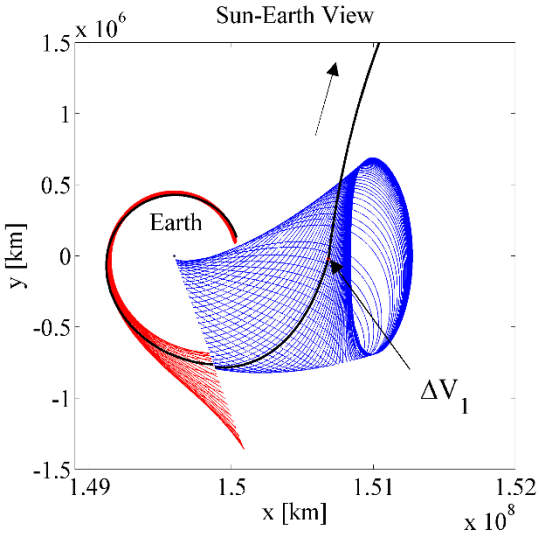


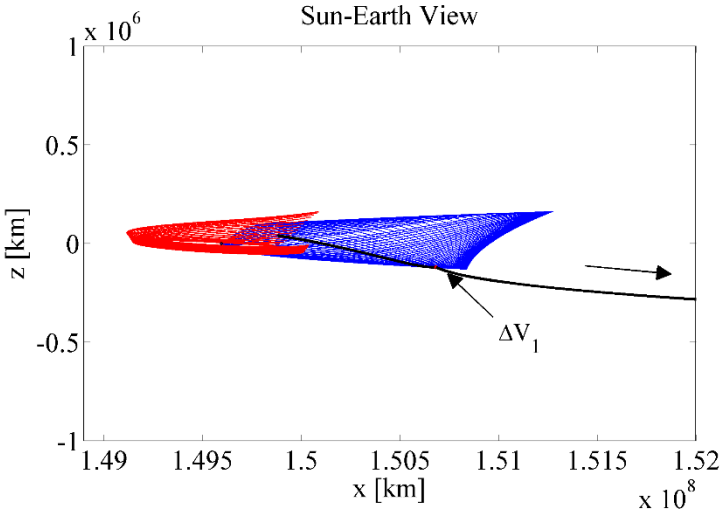
Scenario 1 Guidelines: Sun-Earth Manifold Transfer

- Possible departure dates:
  - Location of the Moon: α, i, β
- Final location of Mars
  - Time-of-flight (TOF): Hohmann transfer
- Targeting Mars
  - Initial guess: Hohmann transfer
    - TOF and ΔV
  - Multiple shooting method
    - Allow two maneuvers



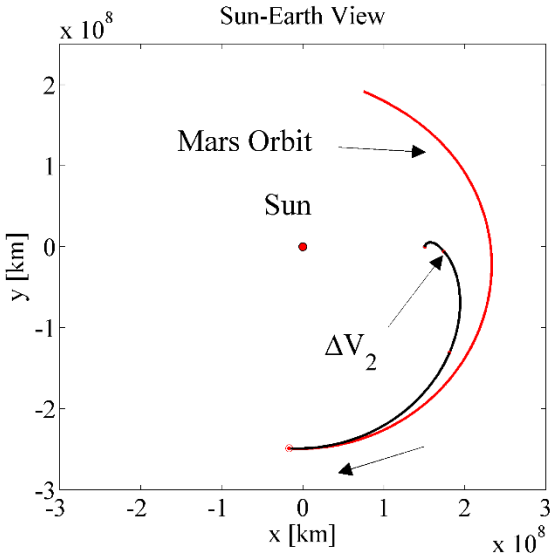
Scenario 1 Sample Results: Sun-Earth Manifold Transfer

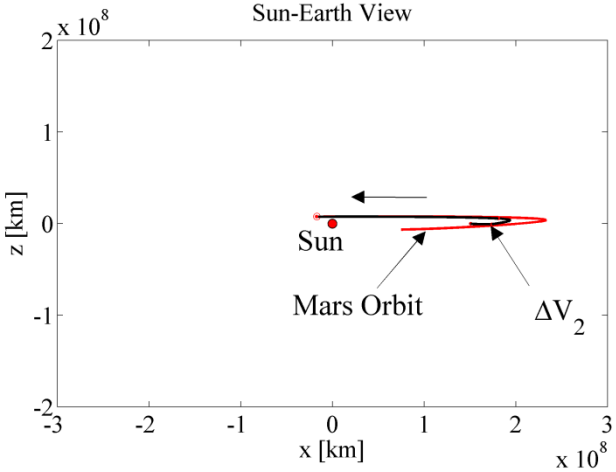




Departure Date: June 16 2022
ΔV: 3.495 km/sec
TOF: 350 days

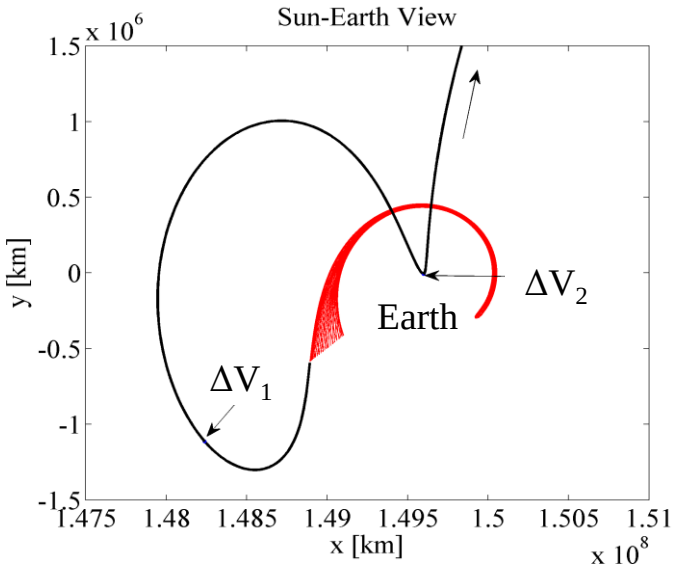
Planar Hohmann Approx.:
ΔV: 2.765 km/sec
TOF: 349 days



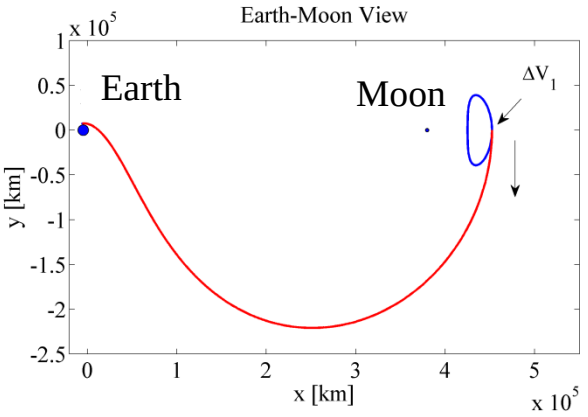


Additional Scenarios

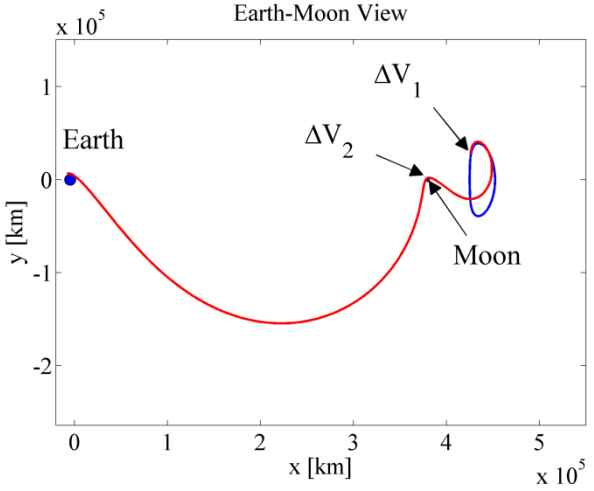
Scenario 2: Earth-Moon manifold transfers



Scenario 3: Direct transfers



Scenario 4: Transfers with lunar flyby



Development of general procedures

- Total: 4 scenarios
- EML_1/L_2 departures
- Transfers available every 2 years

Sample Results: Blended & Higher Fidelity Models

Higher fidelity model:

- Ephemeris: Sun, Earth, Moon, Mars

Scenario	Model	EMAz [km]	Departure Date	Total ΔV [km/sec]	TOF [day]
SE Manifold Transfer	Blended	25,000	June 16 2022	3.495	350
	Ephemeris	25,000	June 16 2022	3.645	350
EM Manifold Transfer	Blended	25,000	July 3 2028	0.759	380
	Ephemeris	33,000	July 3 2028	0.852	376
Direct Transfer	Blended	25,000	Nov. 4 2026	1.593	272
	Ephemeris	46,000	Nov. 3 2026	1.631	262
Transfer with Lunar Flyby	Blended	25,000	Dec. 1 2028	1.150	249
	Ephemeris	27,000	Dec. 1 2028	1.423	249

Concluding Remarks

Development of general procedure

- Transfers from EML_1/L_2 halo orbits to Mars
  - Blended model constructed
  - Four scenarios introduced
    - Manifold and direct options
  - Maneuver-free transfers between EM and SE systems
  - Results transitioned to higher fidelity model

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Acknowledgement

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