Multi-Revolution Extension of Solar-Perturbed Moon-To-Moon Transfer Families

AAS 21-581

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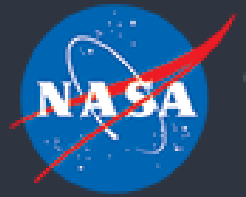
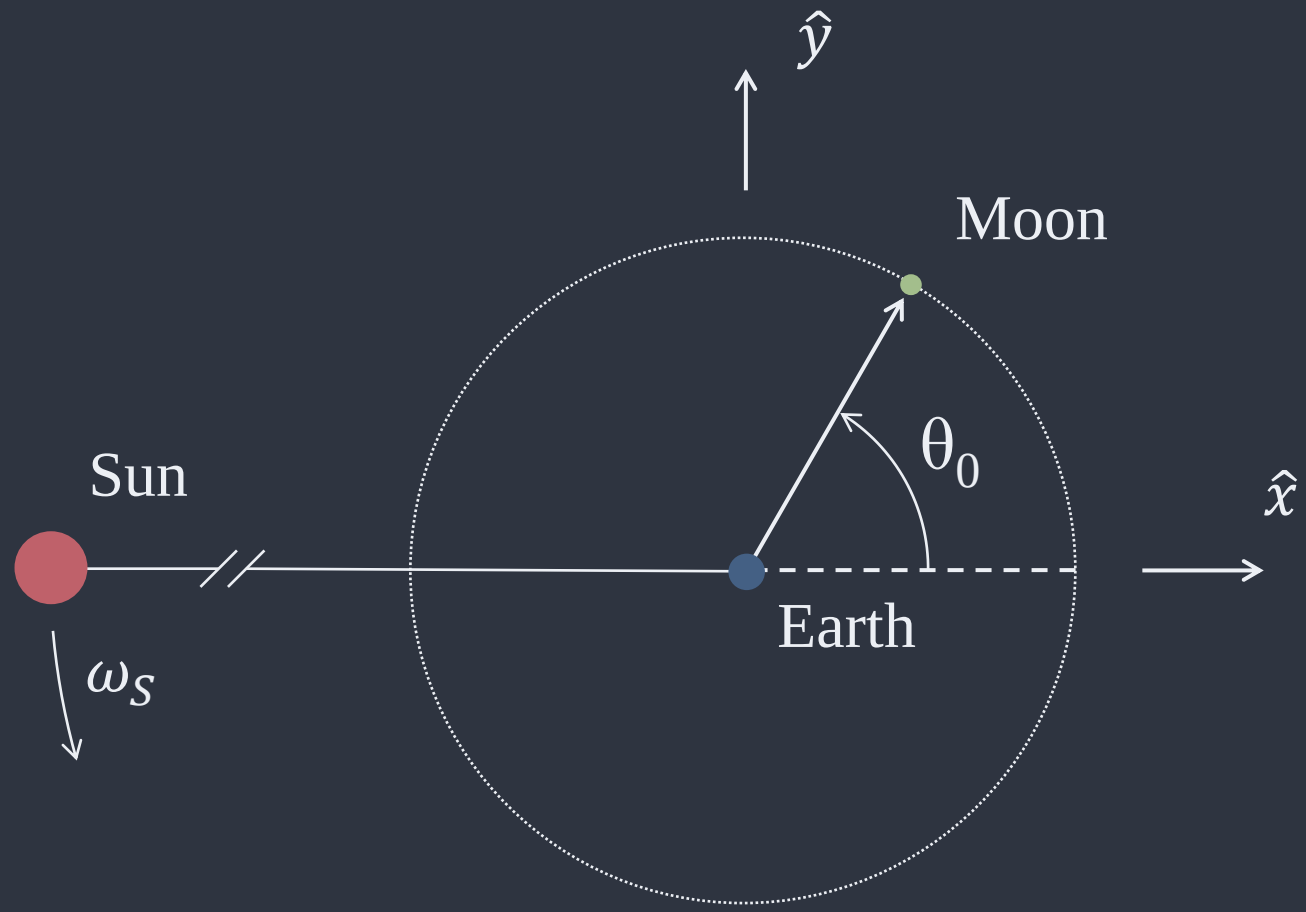


Jet Propulsion Laboratory
California Institute of Technology

Parameters of a Moon-To-Moon Transfer (1/2)

Earth-Moon System Parameters

1. θ: Solar Phase Angle
2. TOF: Transfer time of flight



Equations of Motion

$$\ddot{\boldsymbol{R}} = -\mu_E \frac{\boldsymbol{R}}{\|\boldsymbol{R}\|^3} - \mu_S \left(\frac{\boldsymbol{R} - \boldsymbol{R}_S}{\|\boldsymbol{R} - \boldsymbol{R}_S\|^3} + \frac{\boldsymbol{R}_S}{\|\boldsymbol{R}_S\|^3} \right)$$

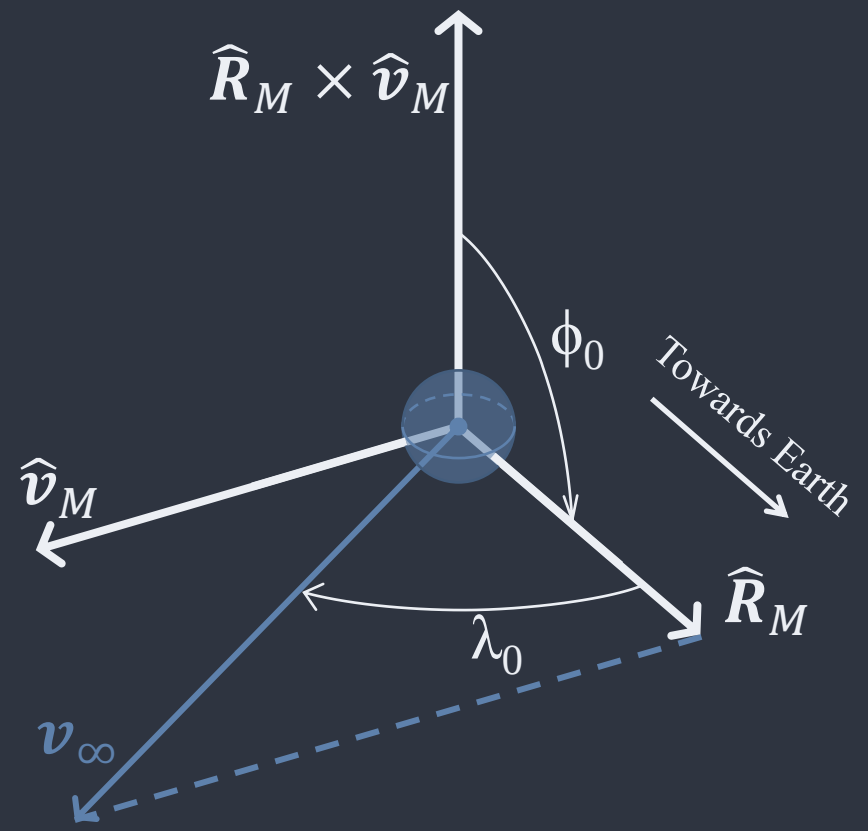
Parameters of a Moon-To-Moon Transfer (2/2)

Departure Lunar Flyby Parameters

3. v_∞: Lunar $\vec{v}_\infty$ magnitude
4. λ_0: Lunar $\vec{v}_\infty$ latitude*
5. ϕ_0: Lunar $\vec{v}_\infty$ longitude†

Arrival Lunar Flyby Parameters

6. ϕ_f: Lunar $\vec{v}_\infty$ longitude†

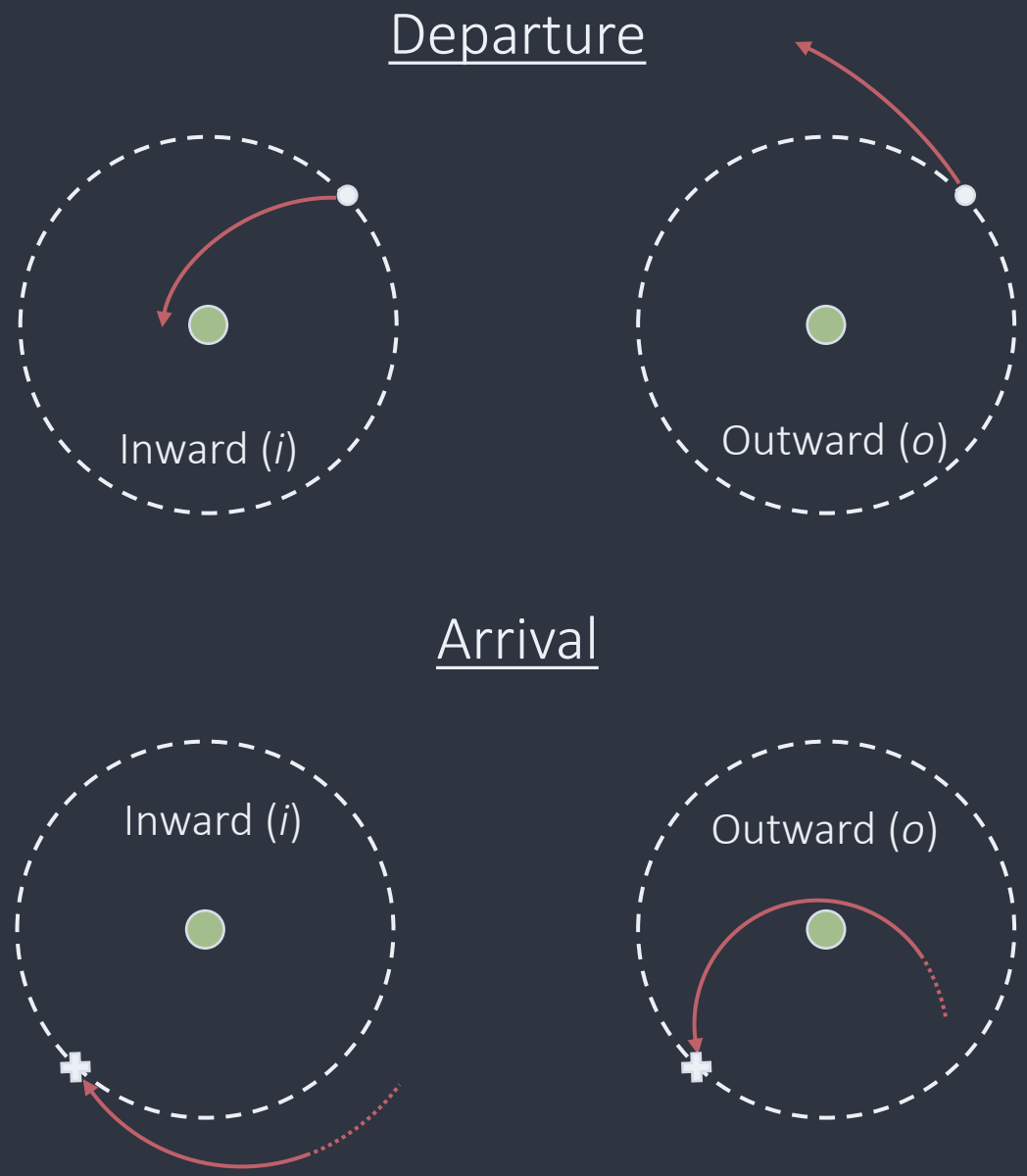


*: Continuous [-90°, 90°]

†: Discrete {-90°, 90°}

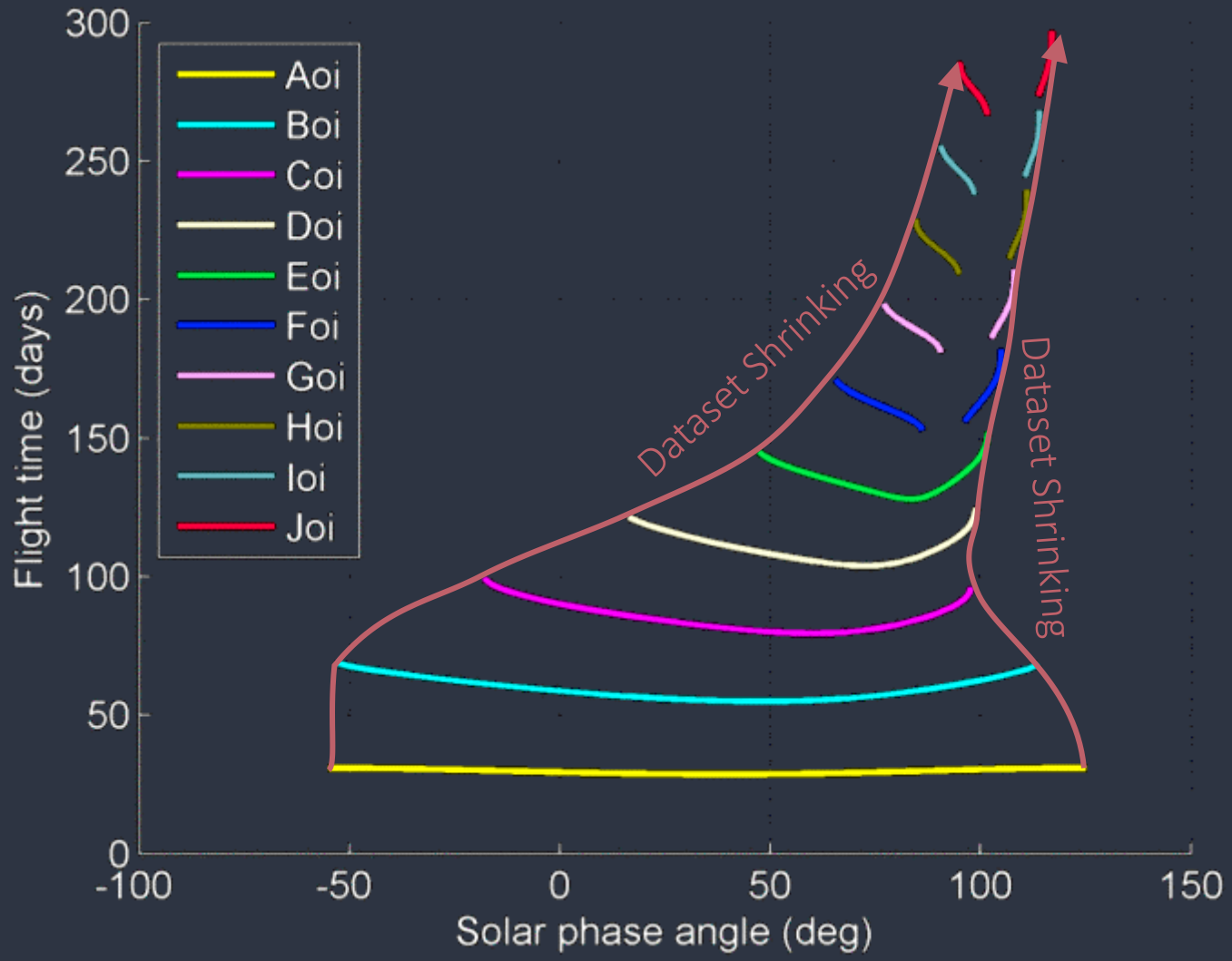
Transfer Nomenclature

- Orbits are categorized by time of flight:
  - A: ~1 month & ~1 Lunar Orbit
  - B: ~2 month
  - ⋮
  - F: ~6 month
- Each letter is then sub-divided by initial and final states
  - i: For $\vec{v}_\infty$ longitudes of 90°
  - o: For $\vec{v}_\infty$ longitudes of -90°



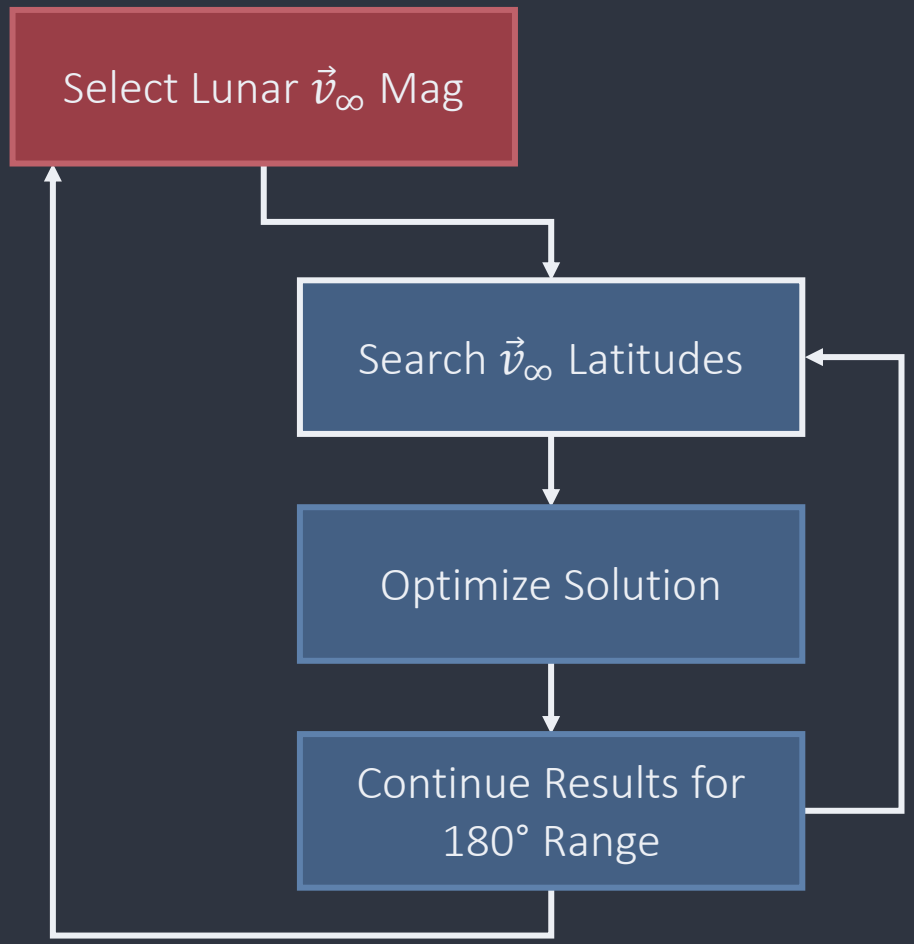
Overview of Current Dataset

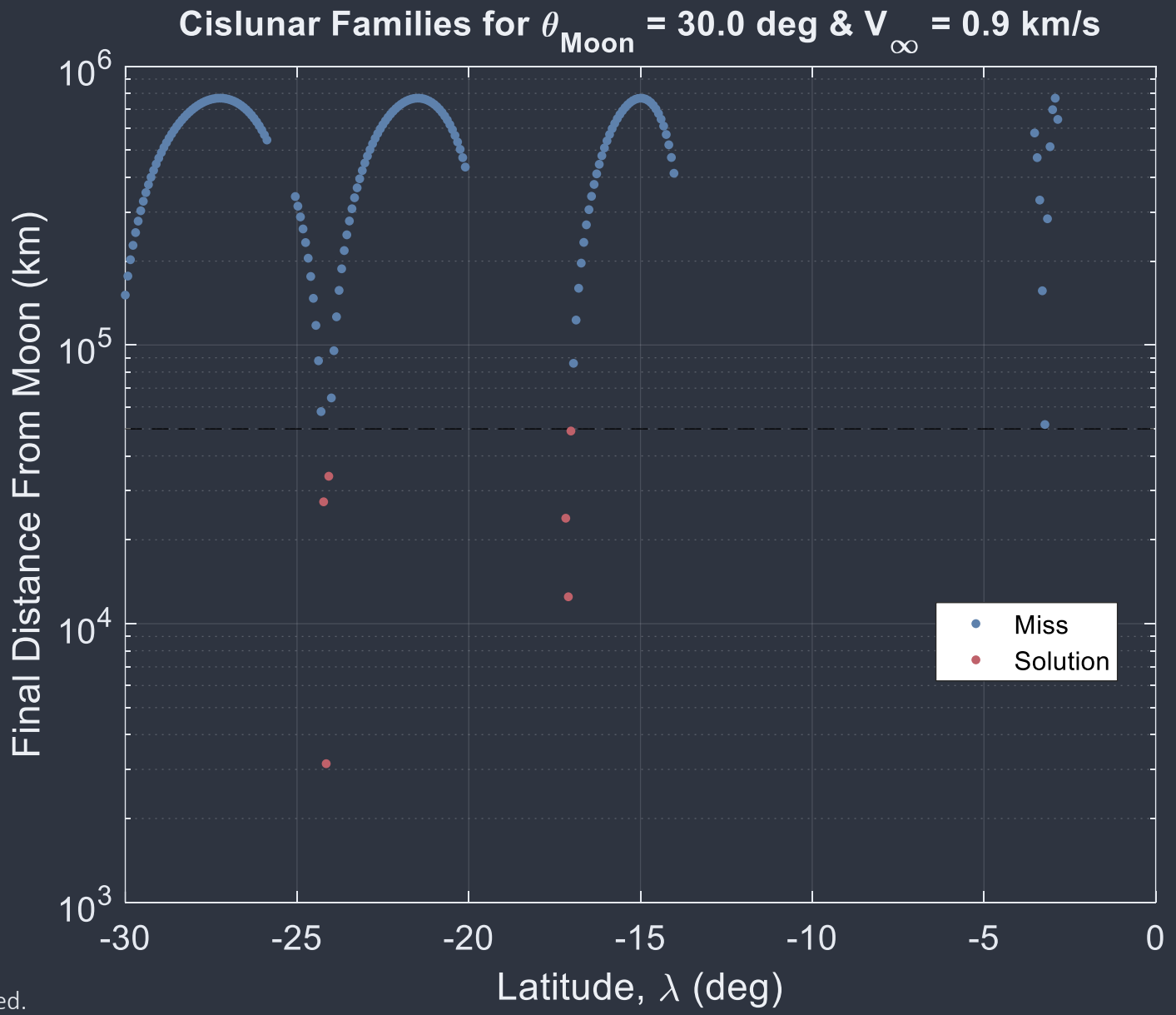
- Has coverage for large majority of useful families for each $\vec{v}_\infty$
- Coverage of initial Solar Phase Angle shrinks as dataset time of flights increase



Credit: Lantoine

Methodology of Building Multi-Rev Datasets





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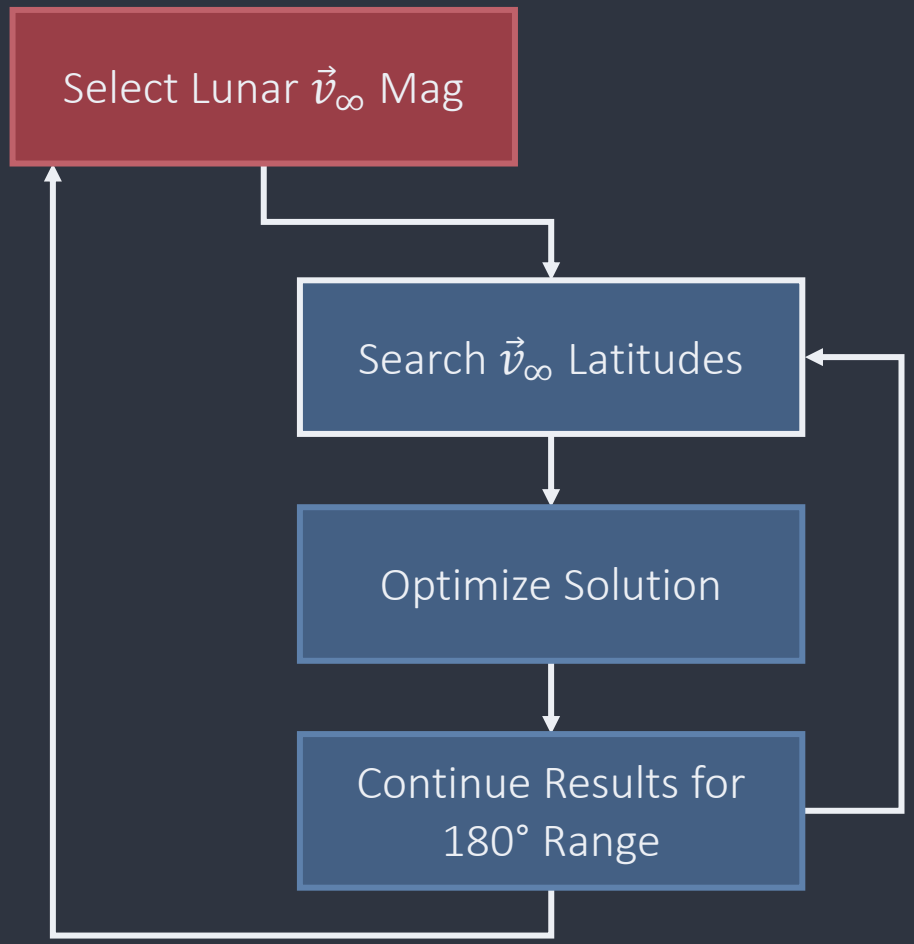

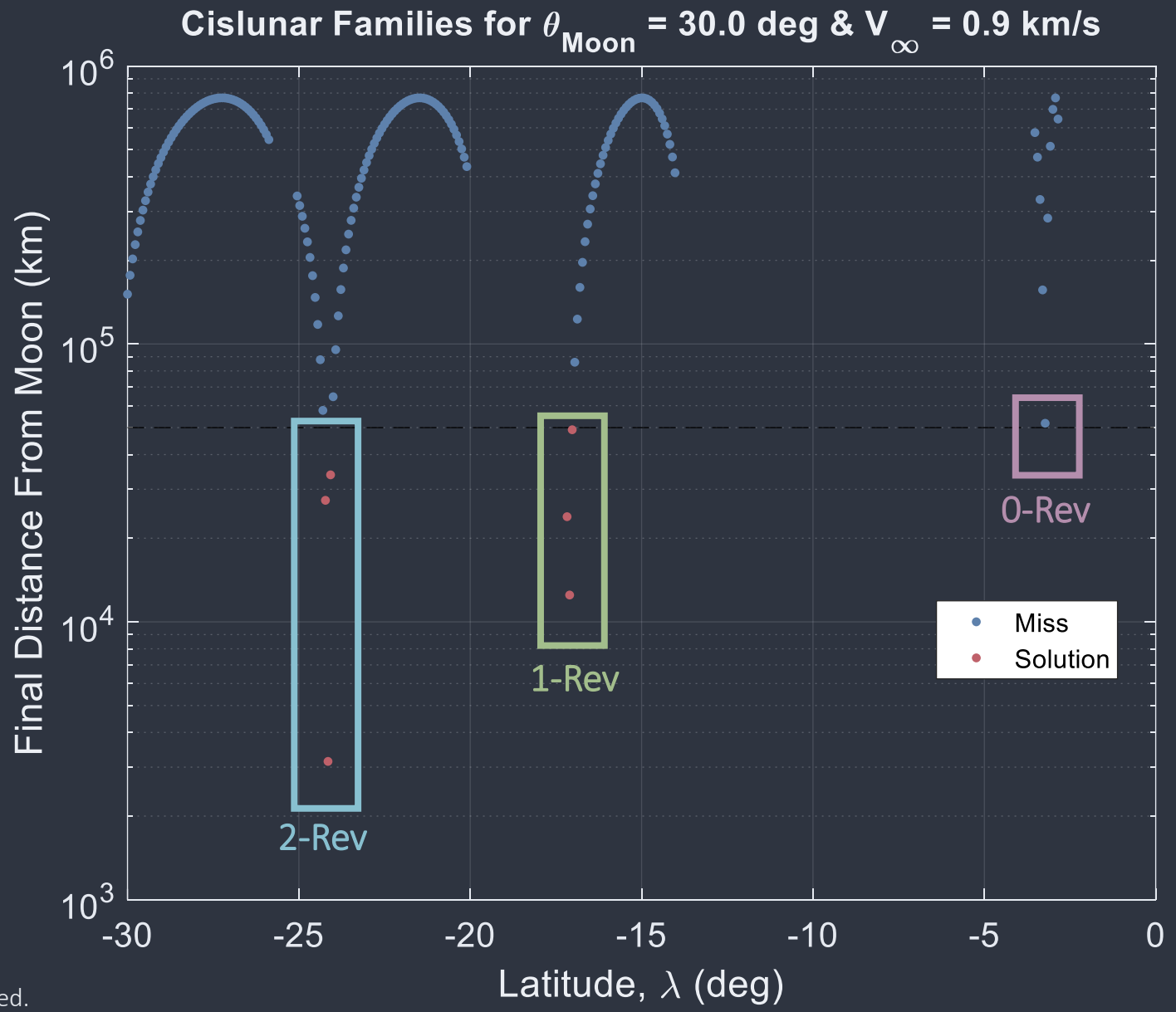

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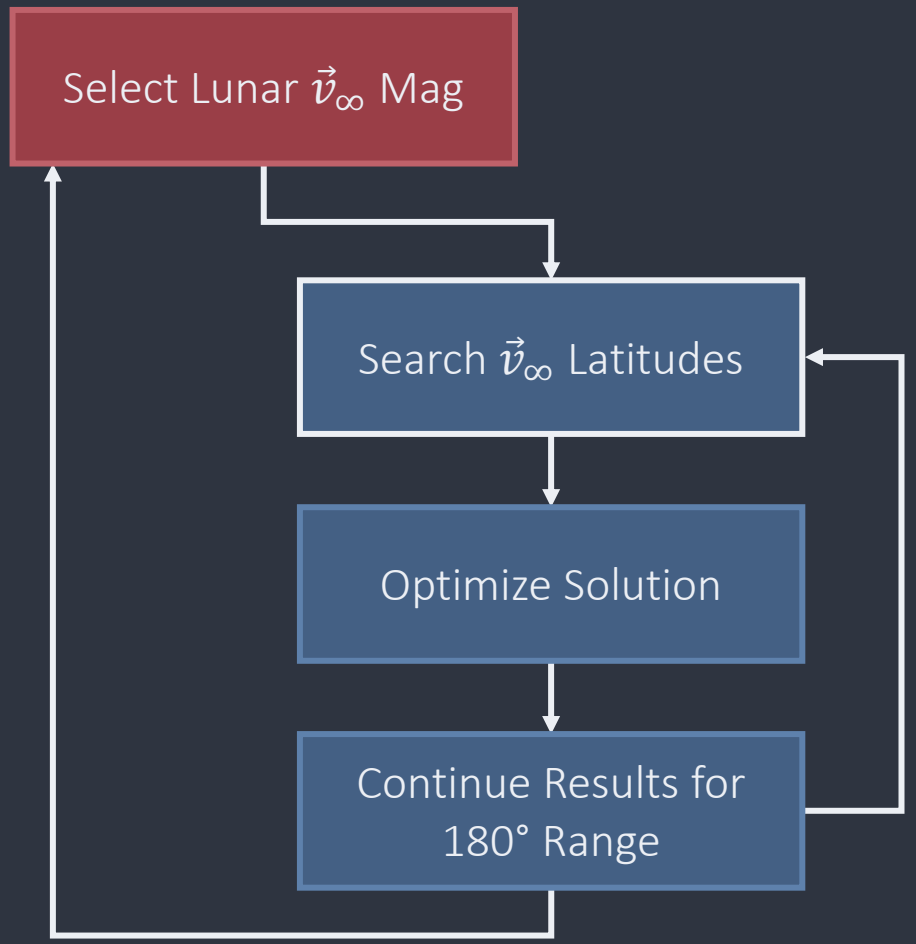

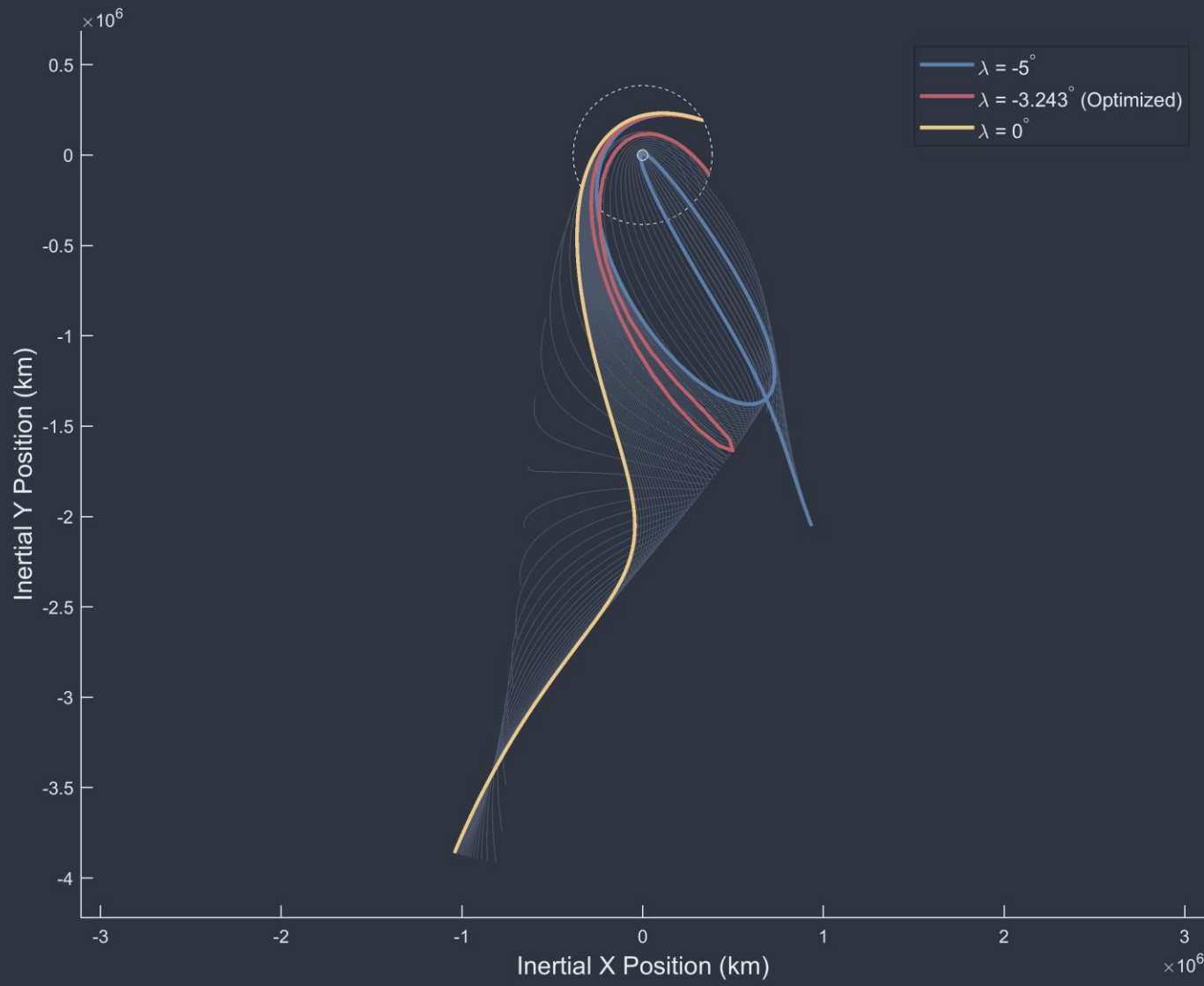

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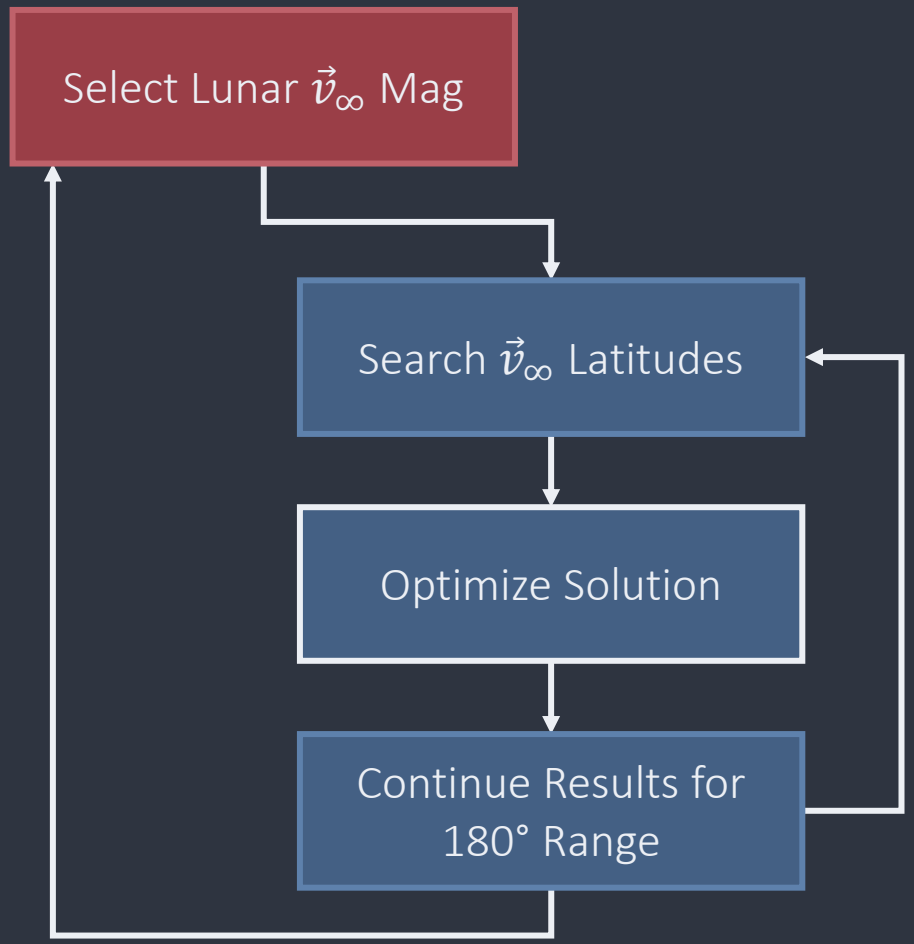

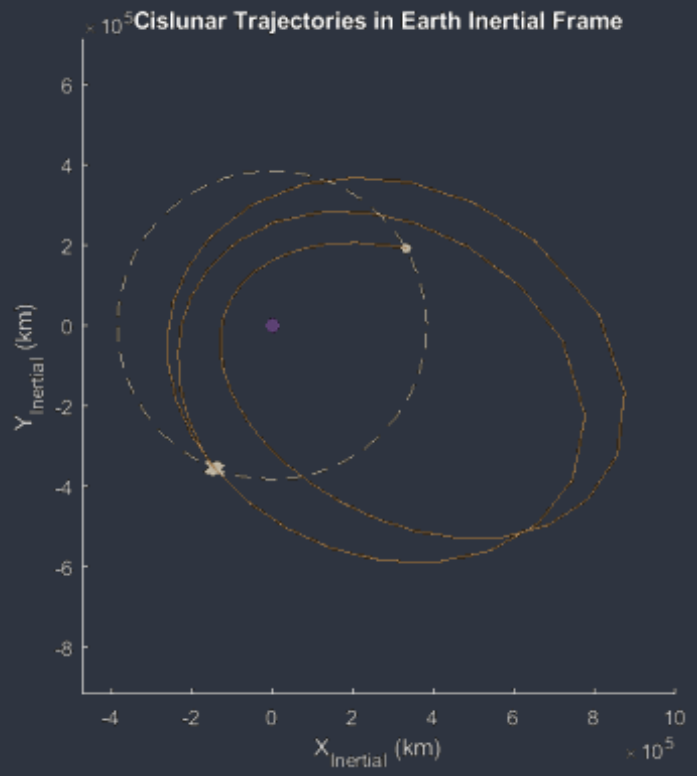

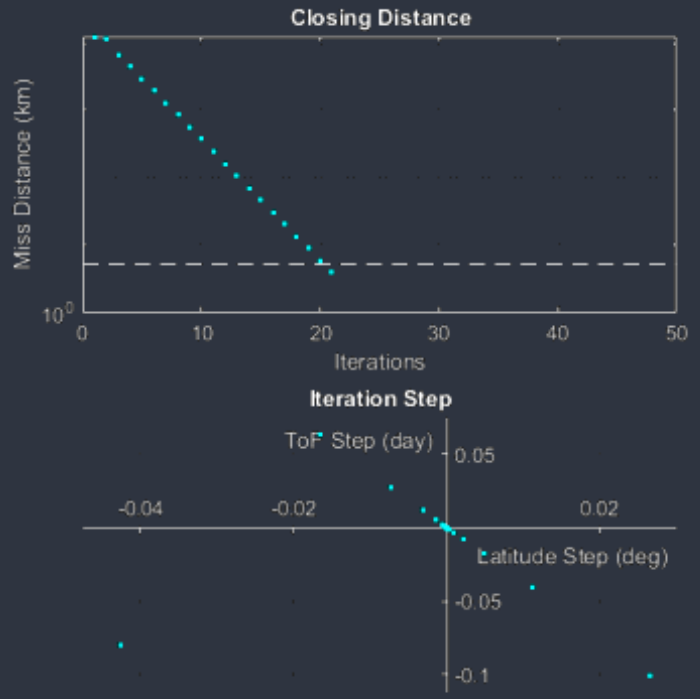

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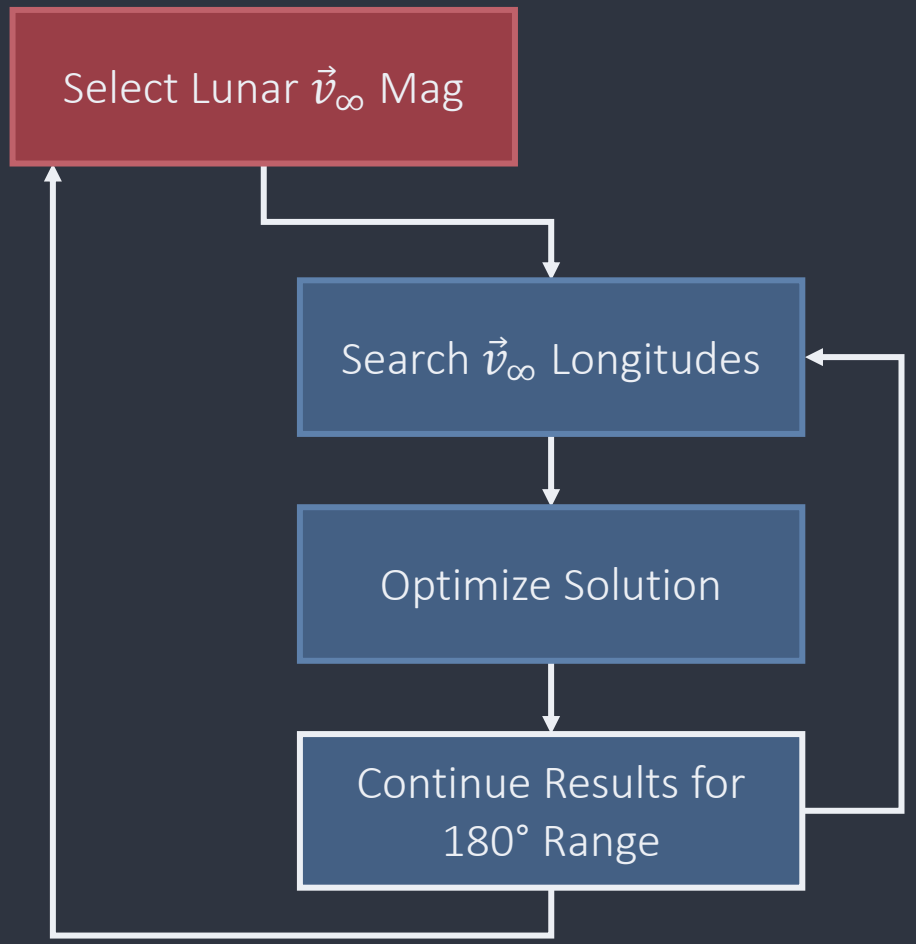

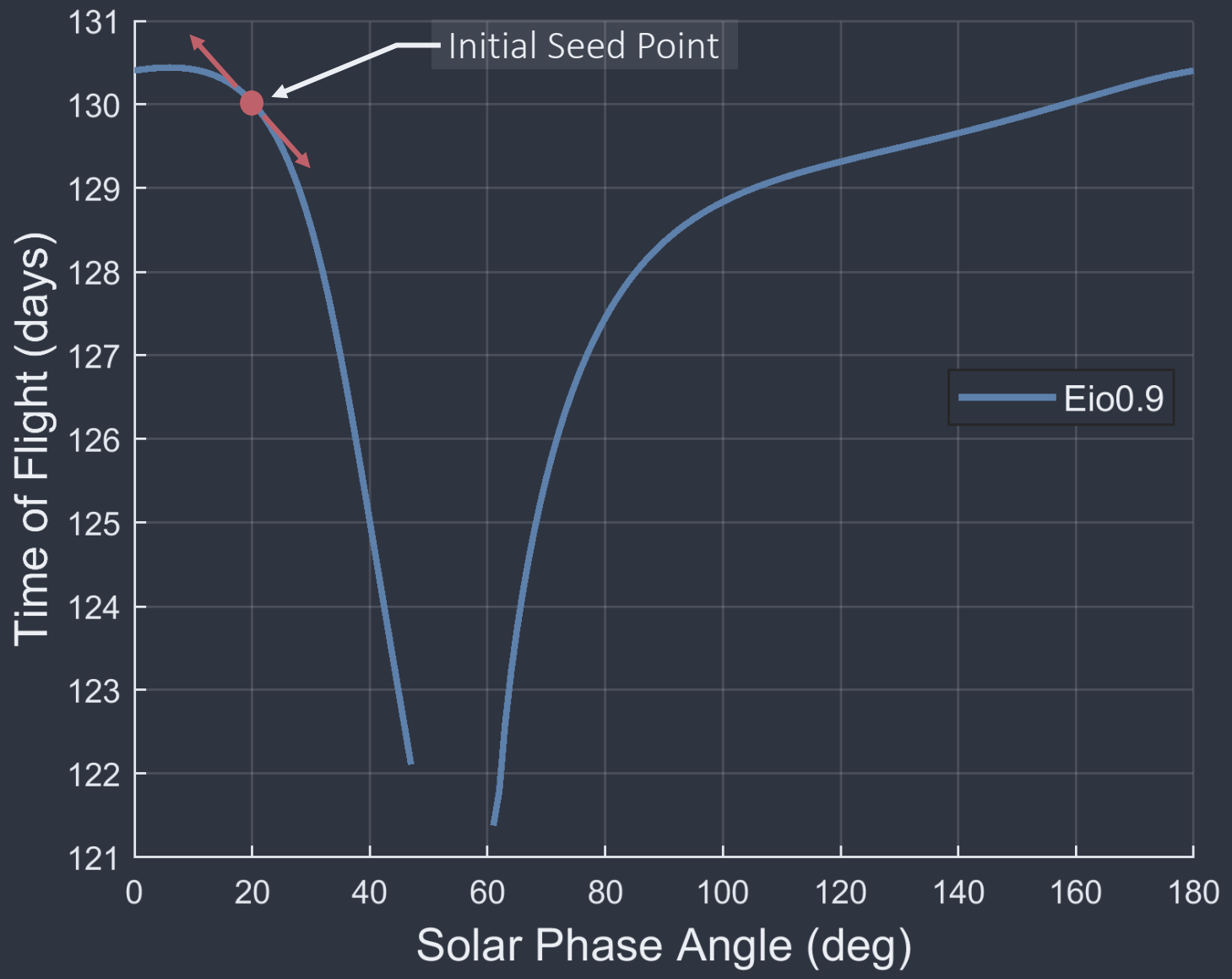

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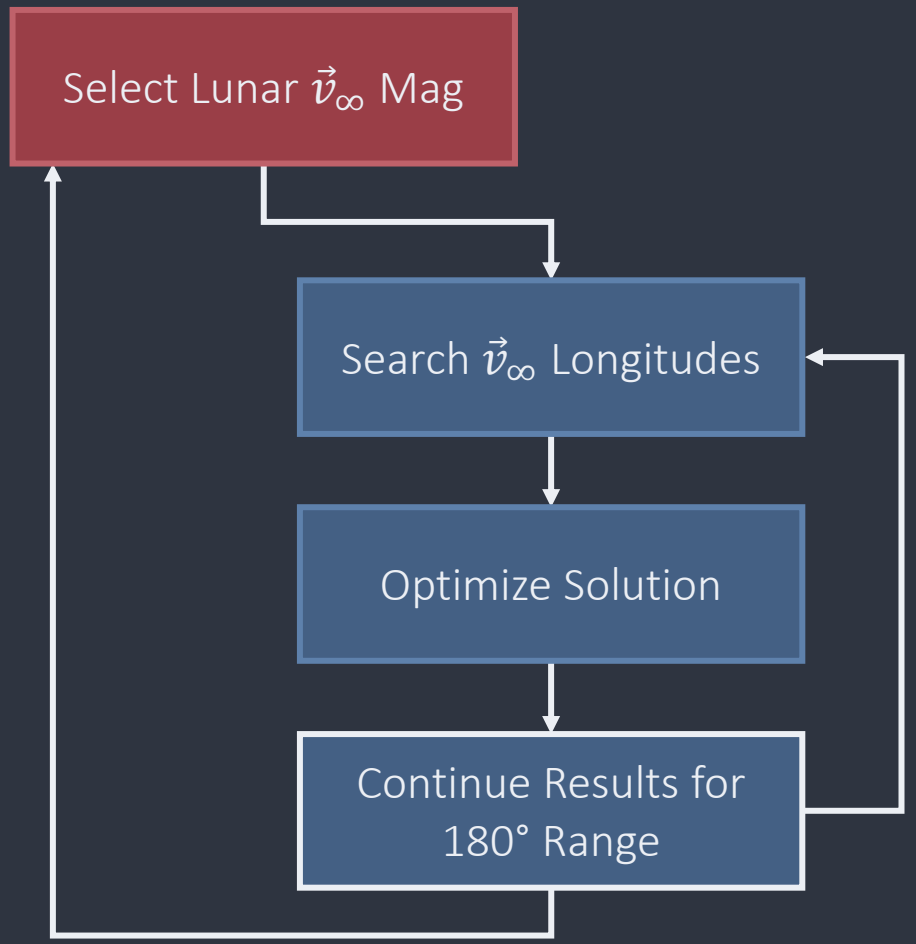
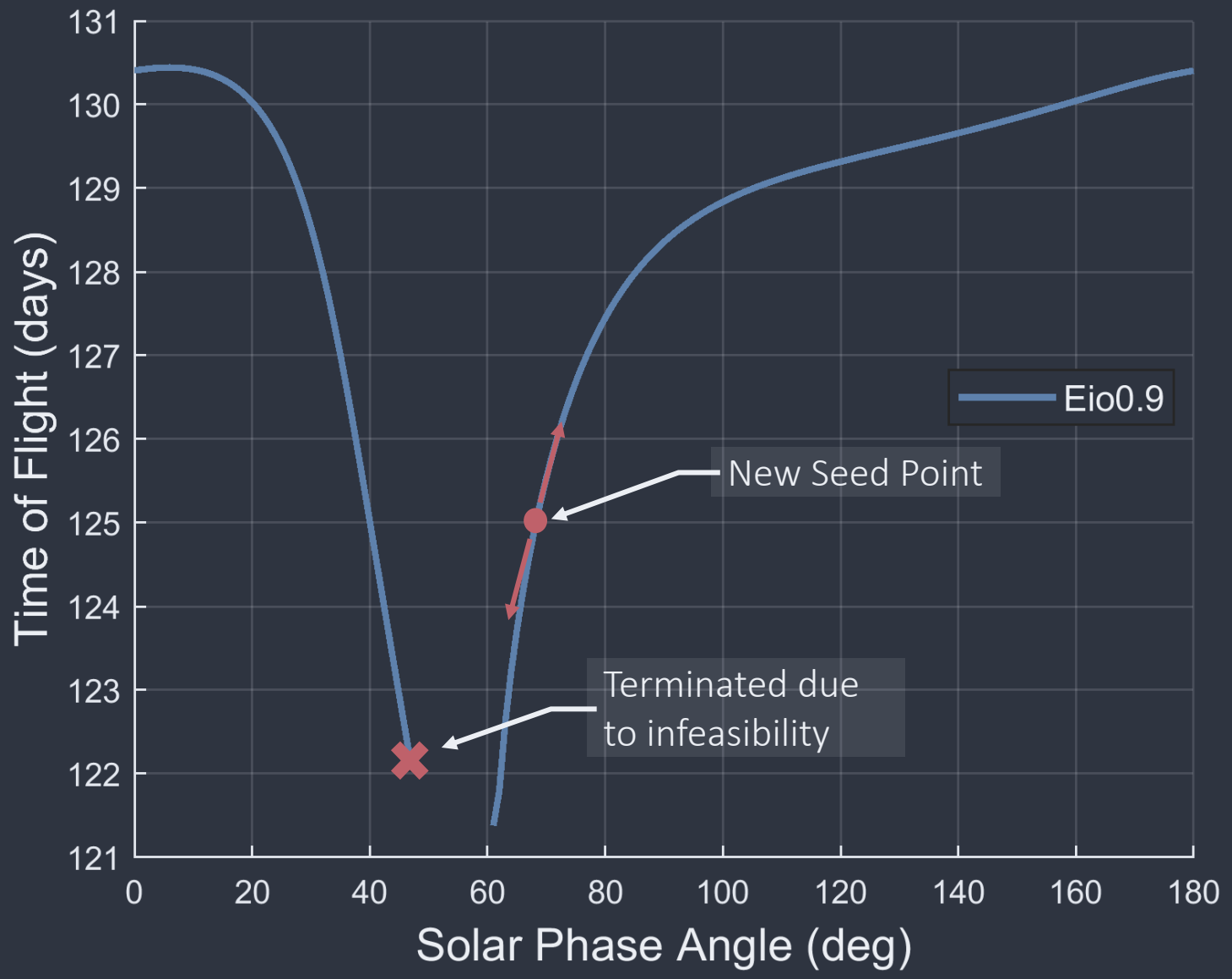
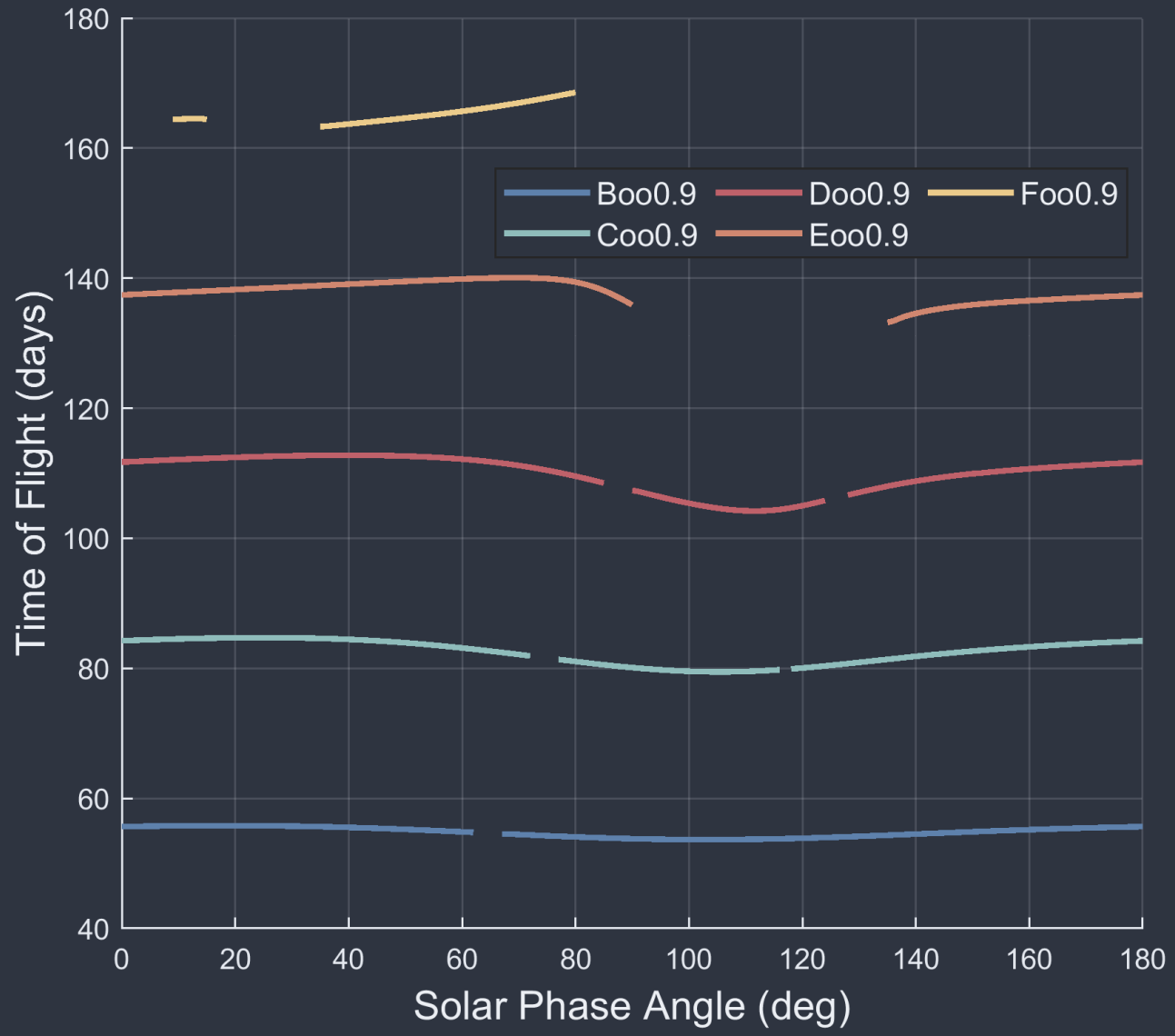




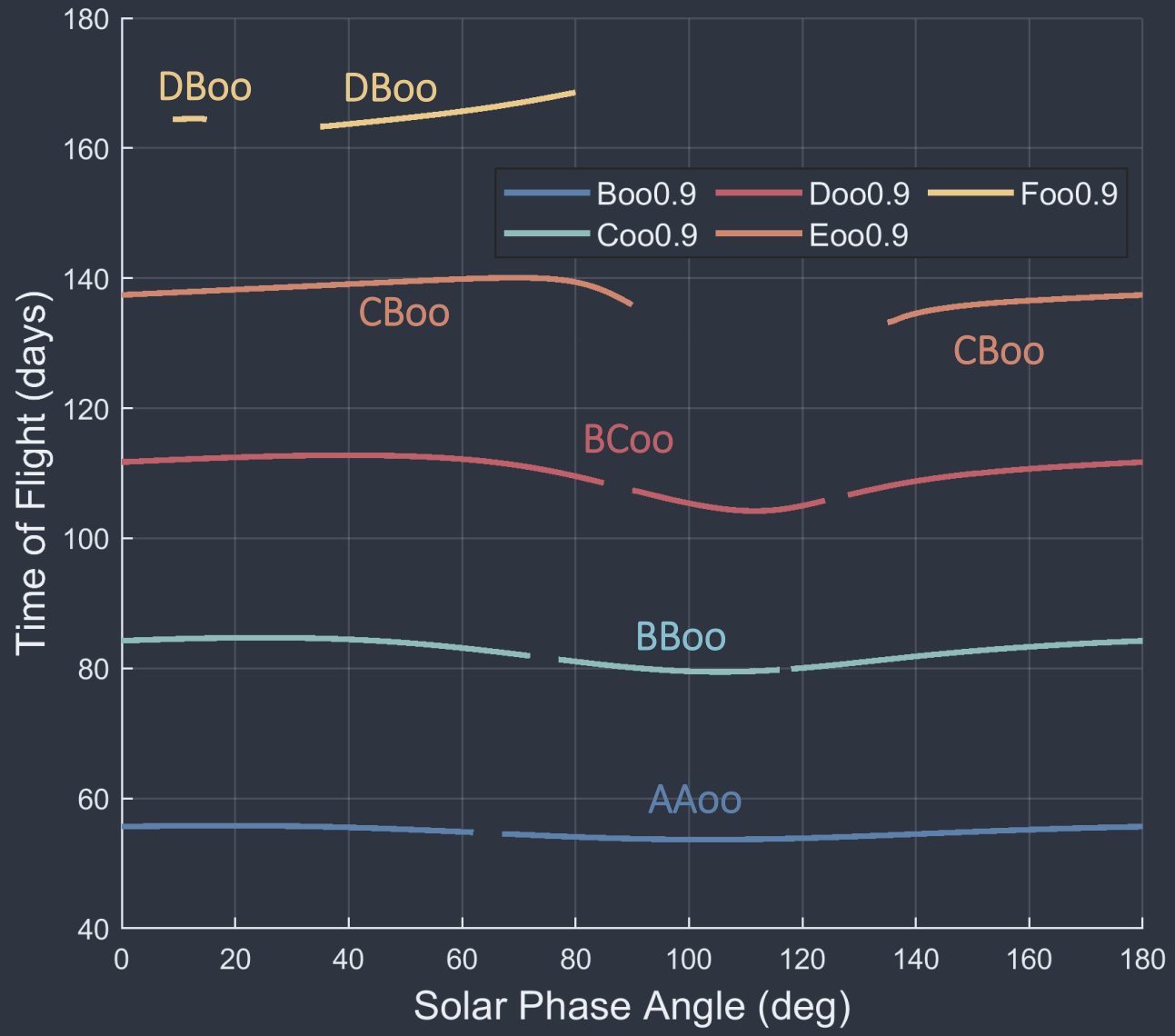
Classifying Multi-Revolution Transfers

- Solutions are first categorized by their total time of flight across all revolutions
- Each discontinuous group is then subdivided into their multi-rev families



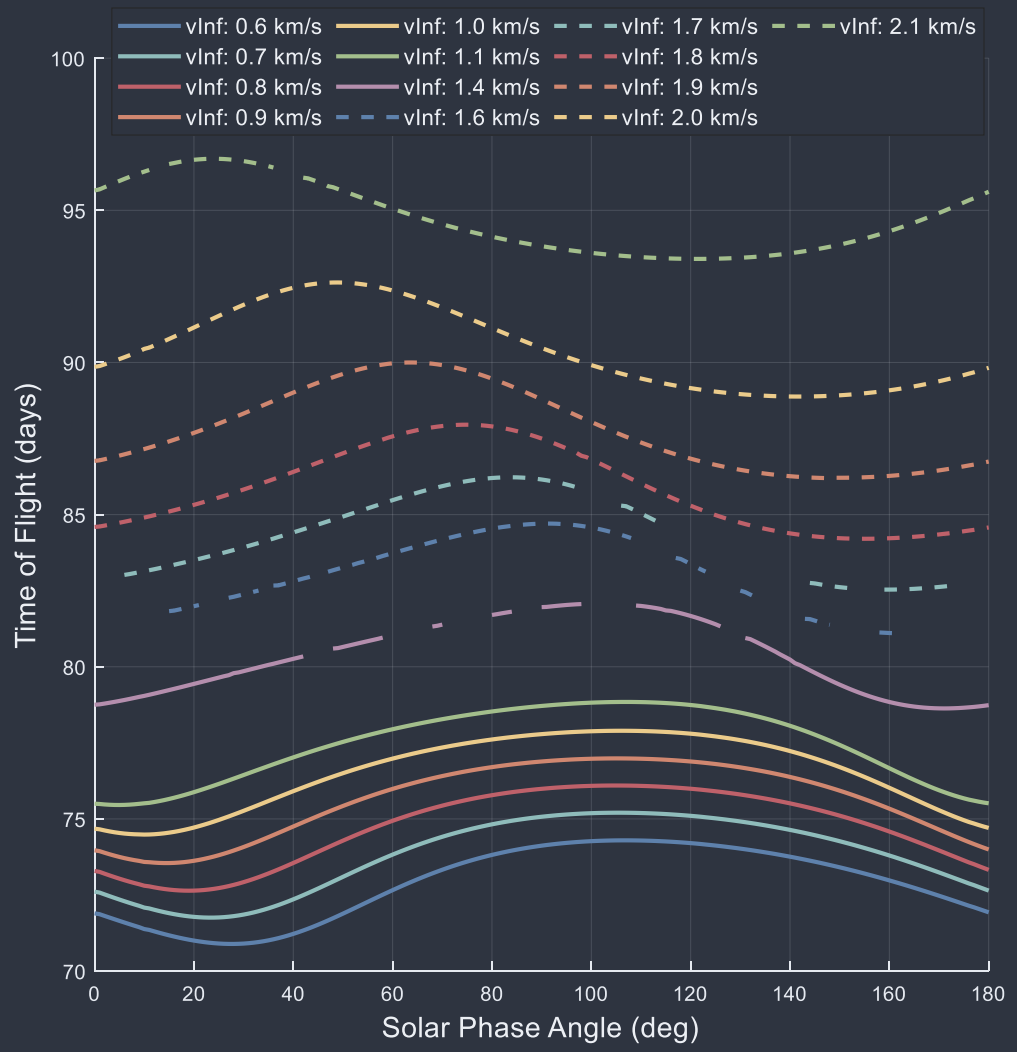
Classifying Multi-Revolution Transfers

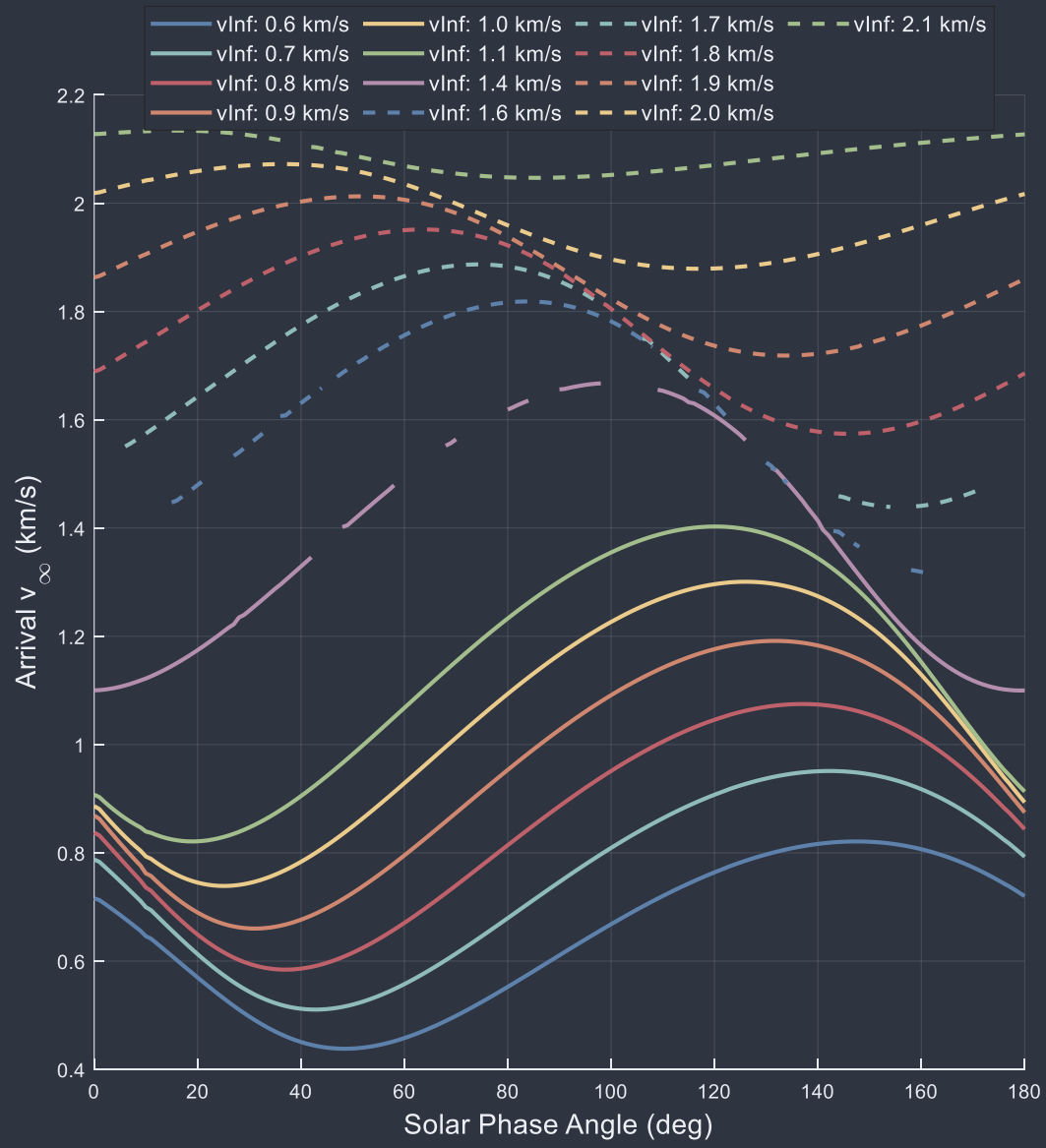
- Each time of flight lettering (A:F), signifies the time to complete each revolution
- Lower time of flight families see little variation in their classifications



Same Families at Different $\vec{v}_\infty$

3-Month (C) “io”





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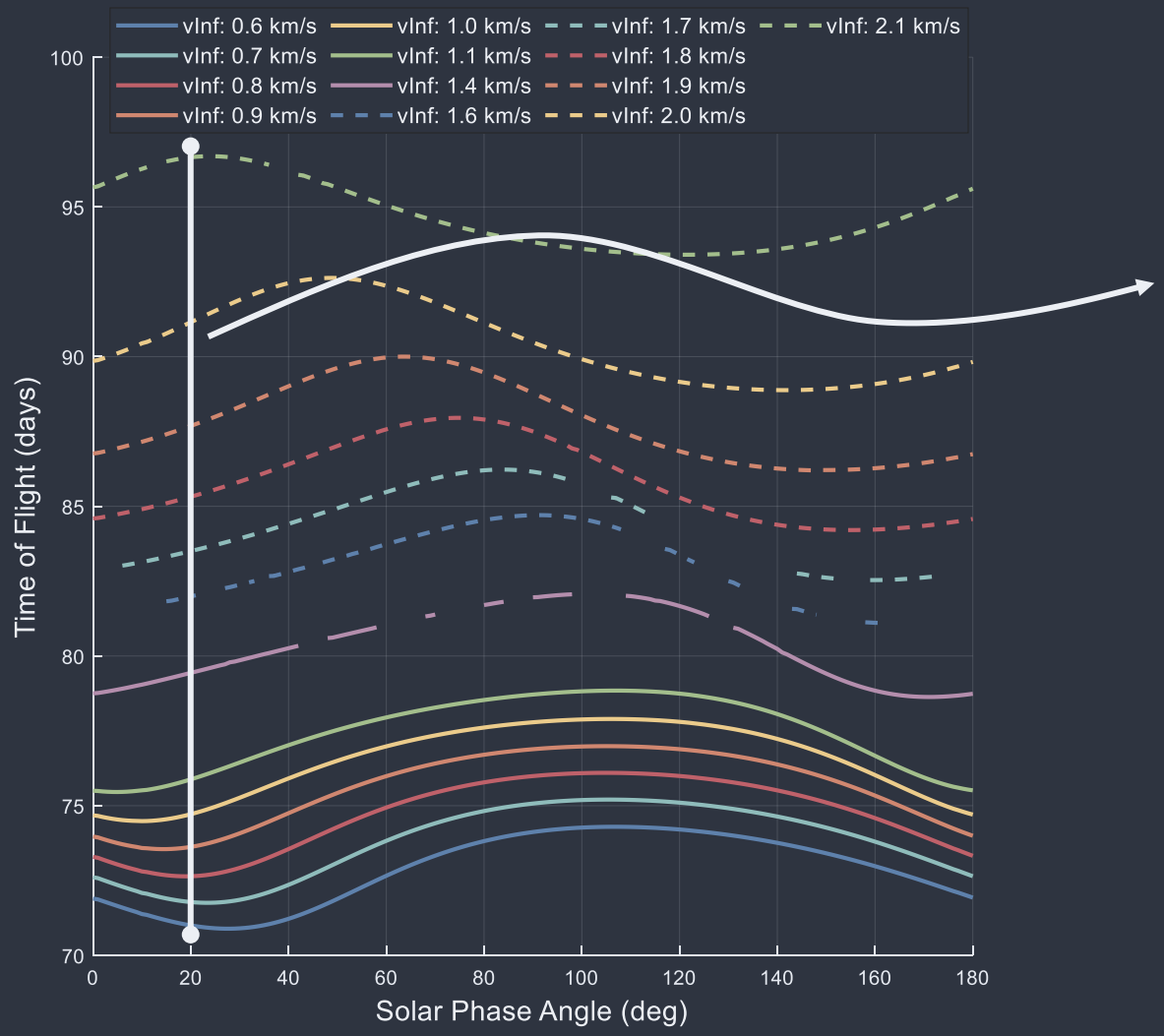

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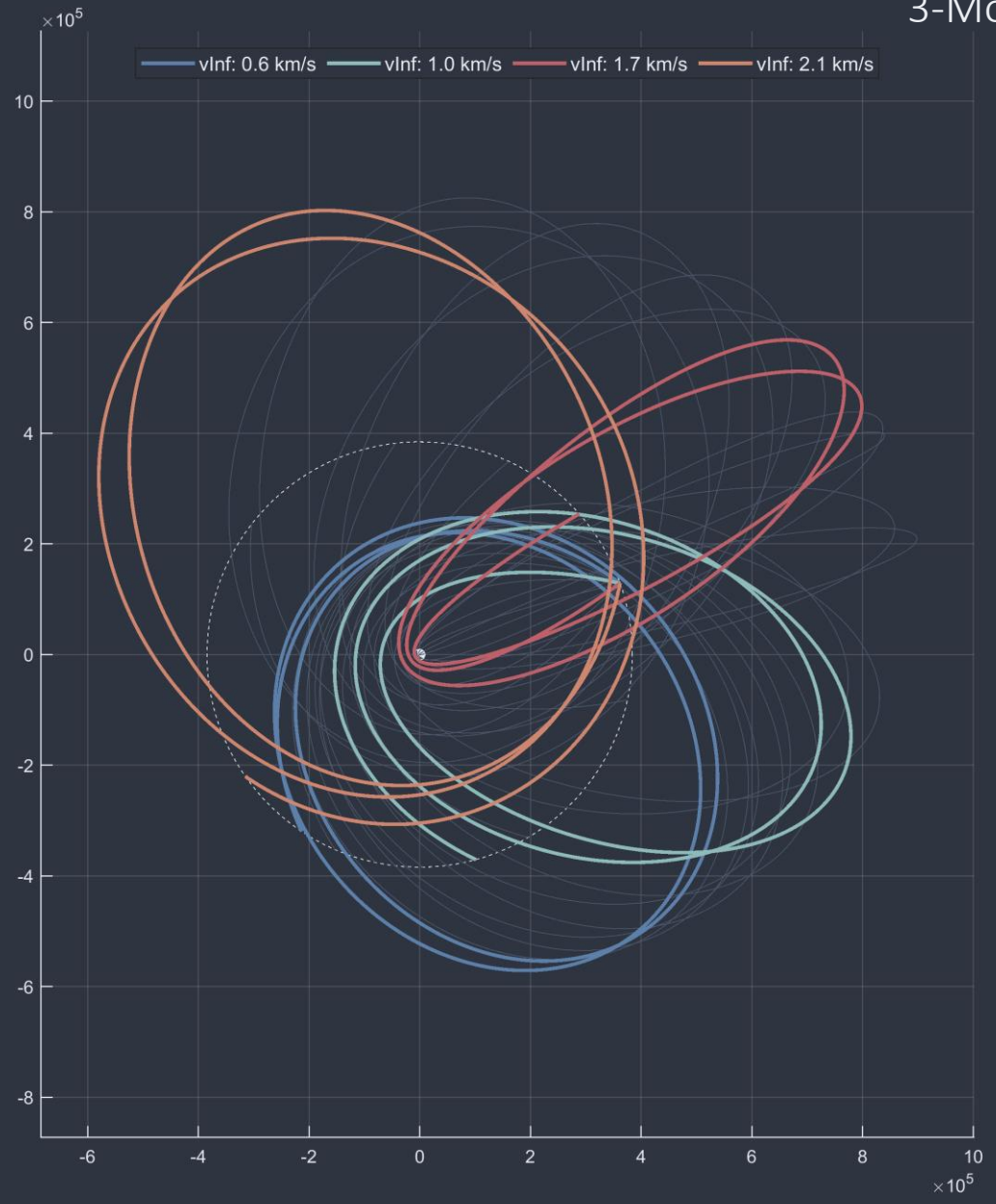
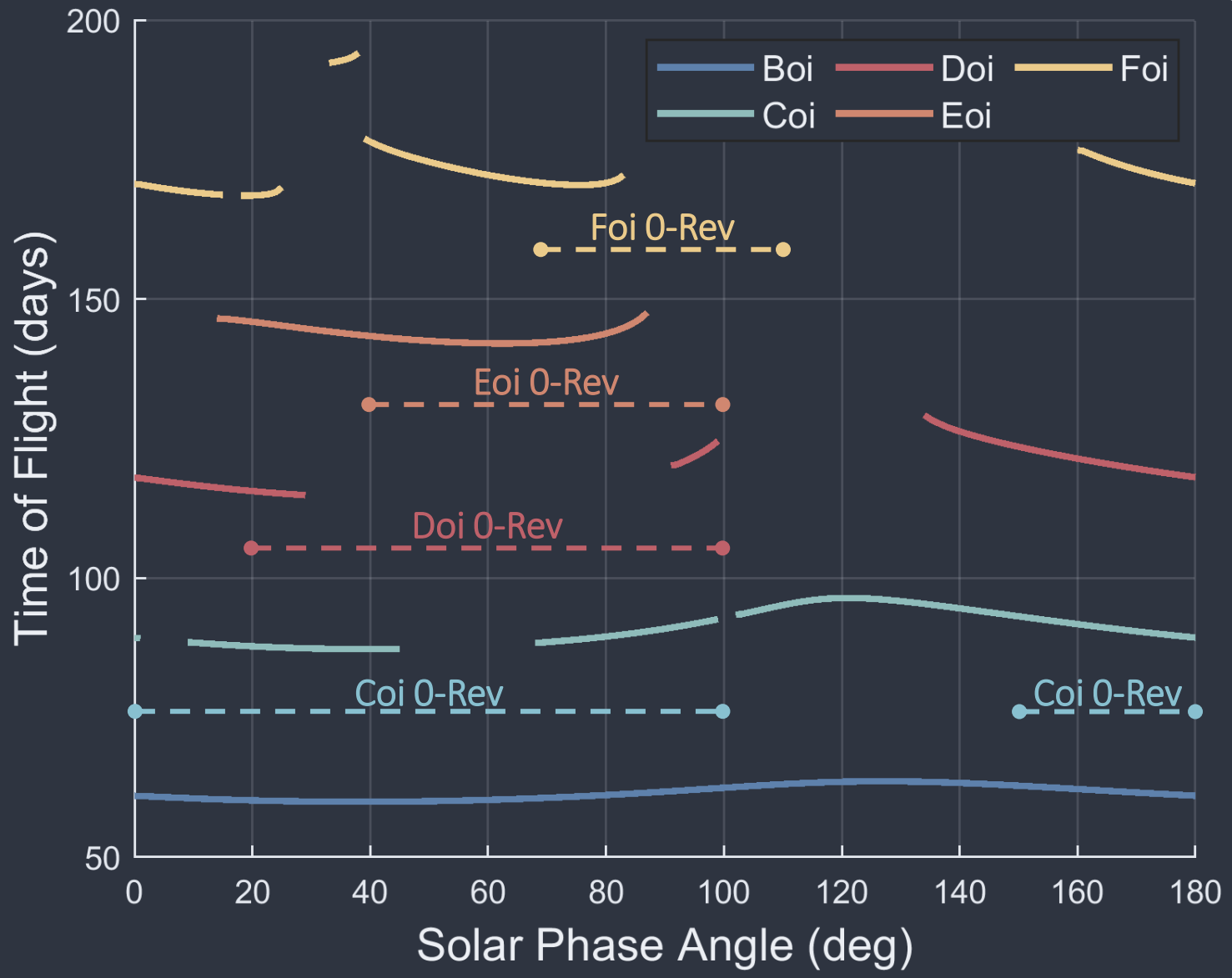


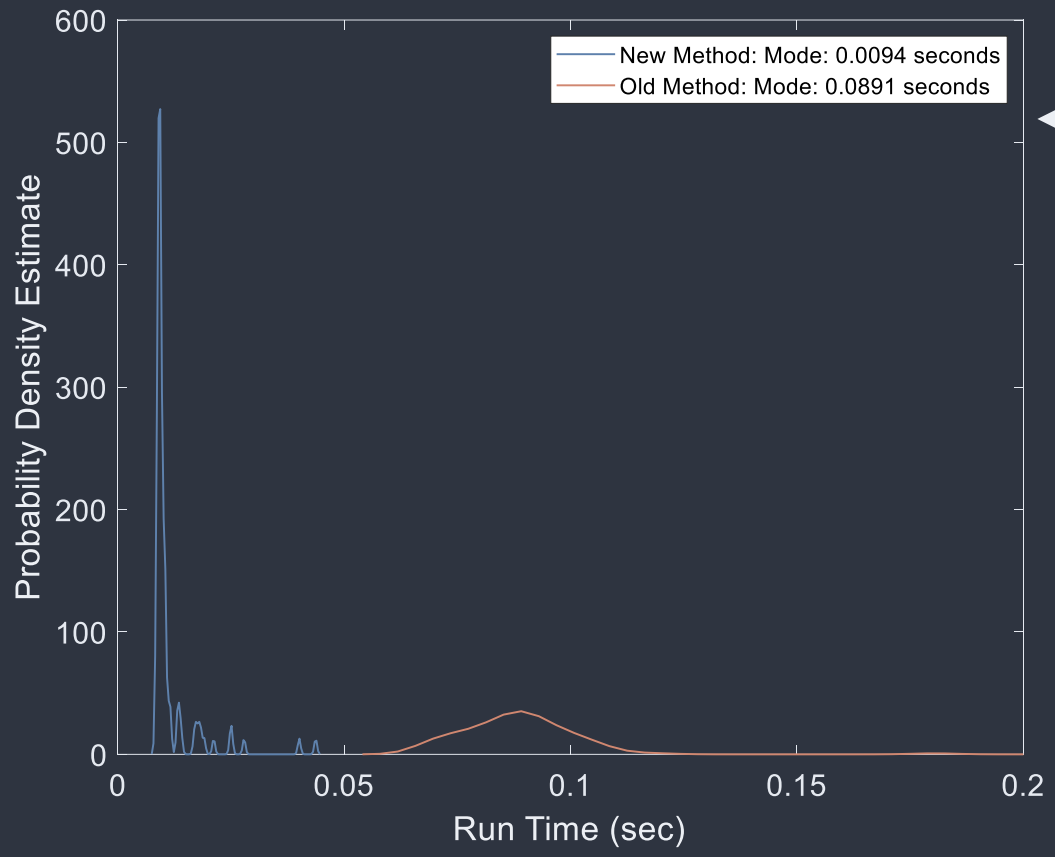
Combining 0 & 1 Rev Solution Spans

"oi" Families @ $\vec{v}_\infty$ = 1.2 $^{km}/_{s}$

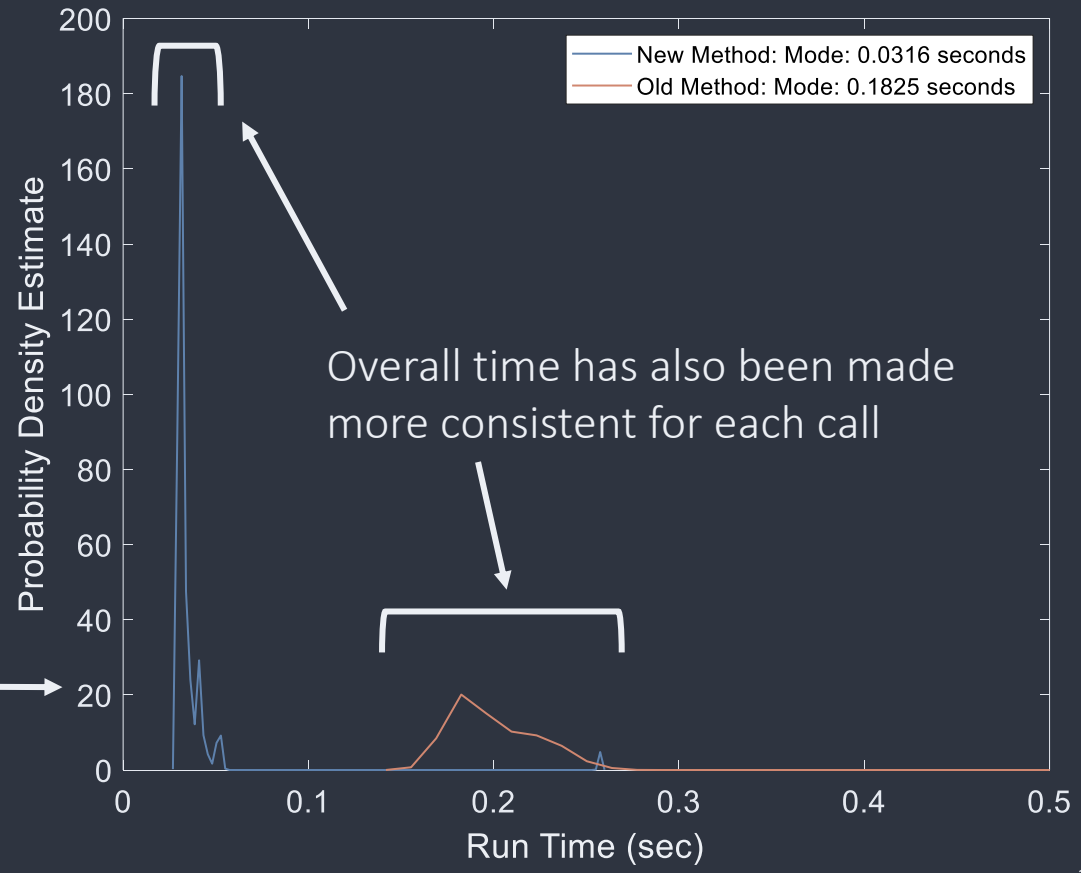


*Dotted lines indicate only phase angle span and **not** ToF

Per-Function Speed Improvements



Shorter functions/Cislunar transfers see larger gains from switching over to a referential database
Roughly 8-10x speed reduction

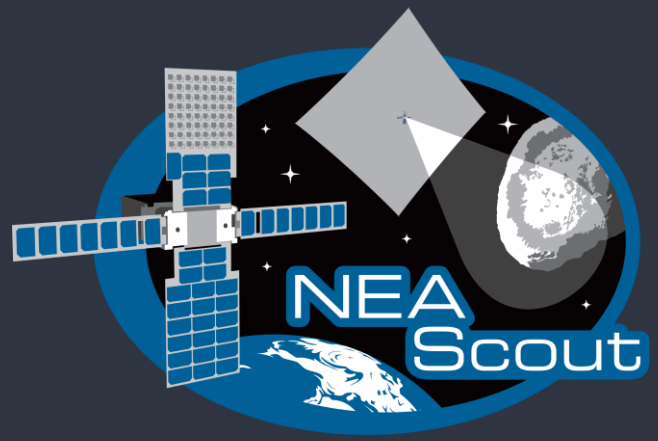


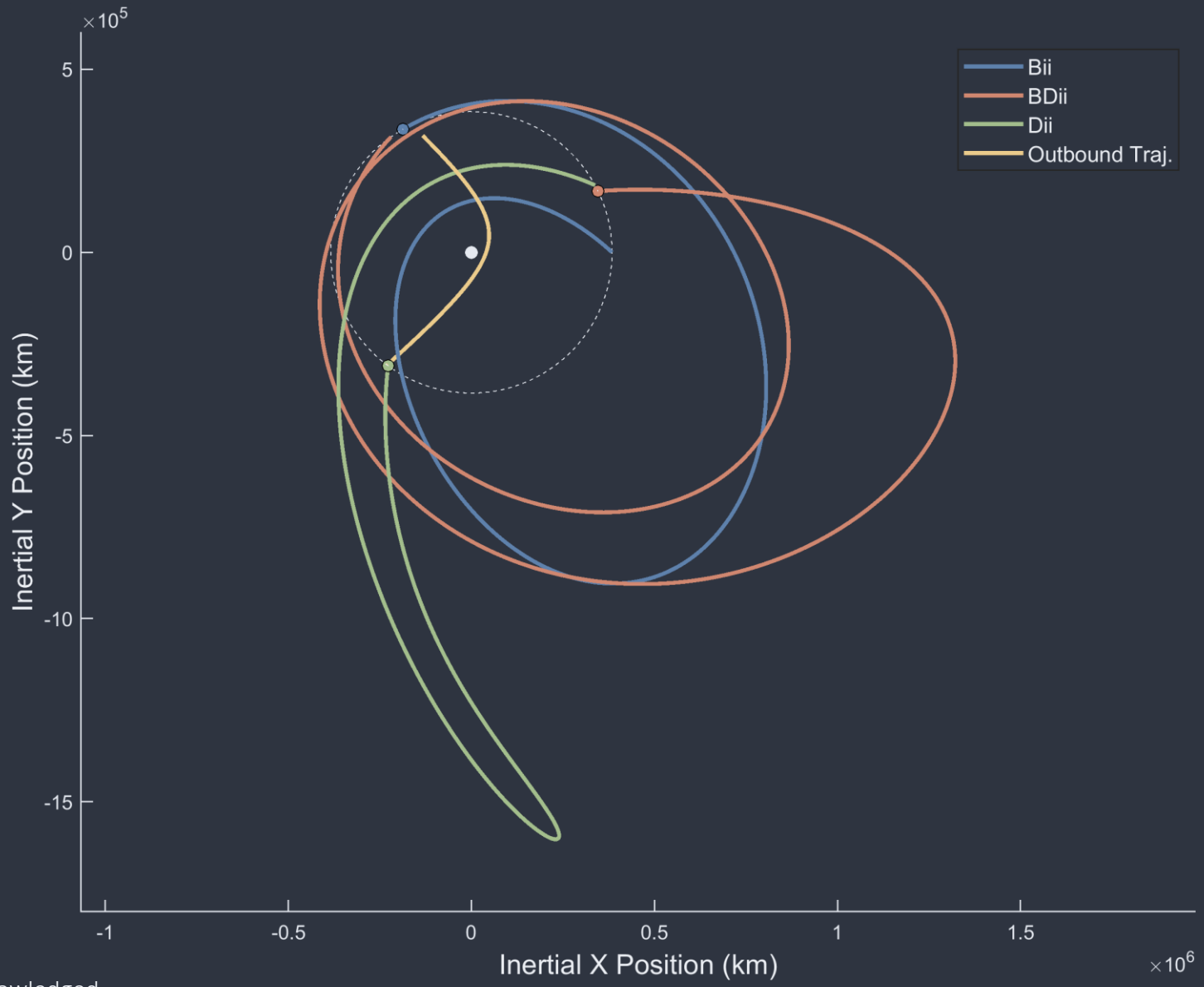
Overall time has also been made more consistent for each call

Longer functions benefit less due to spending more computation time on in-between calculations, such as flybys and eclipses
Roughly 5-7x speed reductions

Multi-Revolution Results from Broad Search

- Seq: BiiBDiiDii
- Departure and Arrival*:
  - Dep: Oct 03, 2021
  - Arr: Jan 01, 2024





*At asteroid 2020GE

Closing Remarks

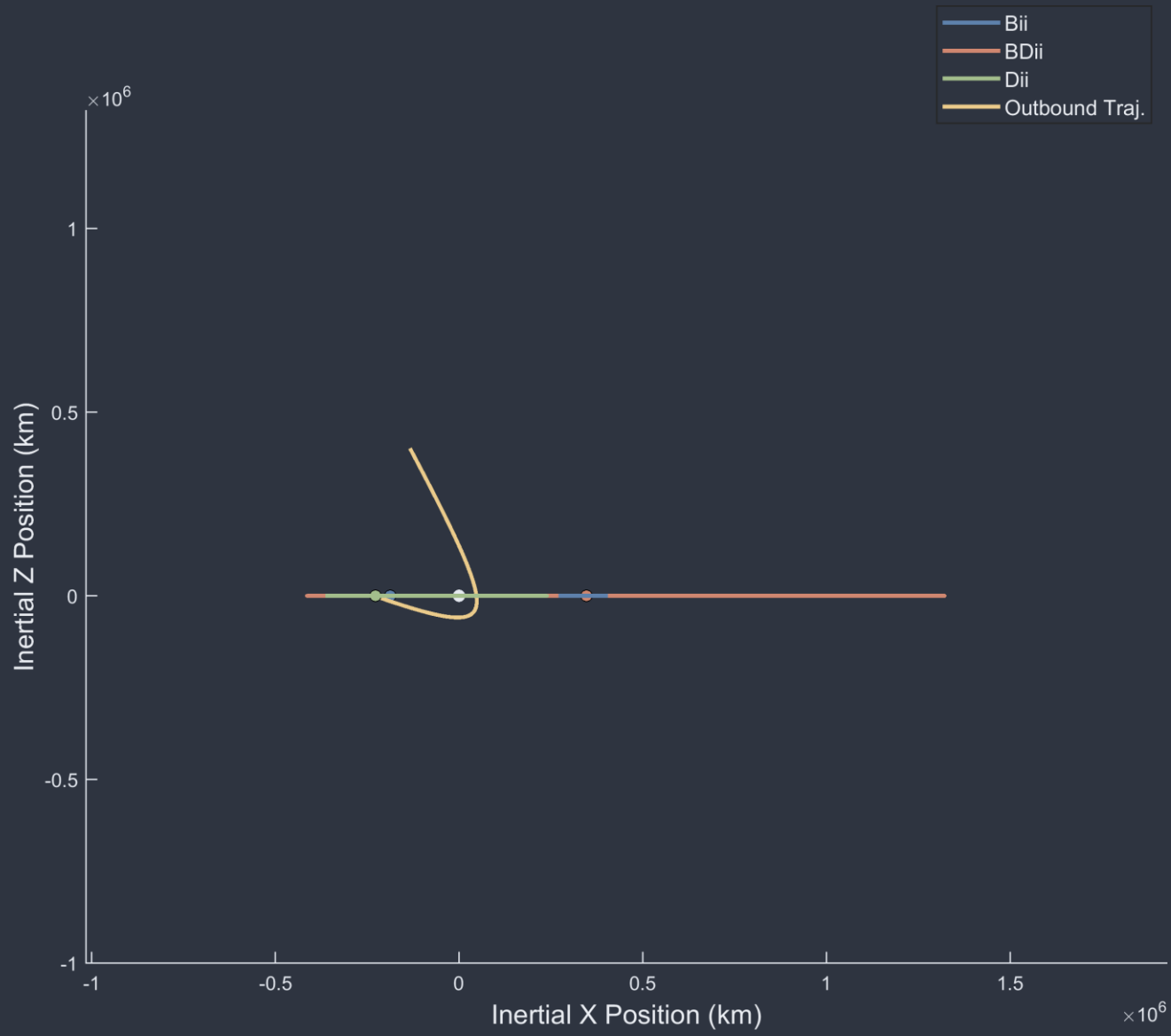
- Defined methodology for initializing, building, and categorizing Moon-To-Moon trajectory families
- Developed naming convention to illustrate overarching structures in multi-revolution datasets
- Demonstrated speed boost in broad search contexts
- Applied multi-revolution results to find novel solutions to future space missions such as NEA Scout

For any questions regarding the paper

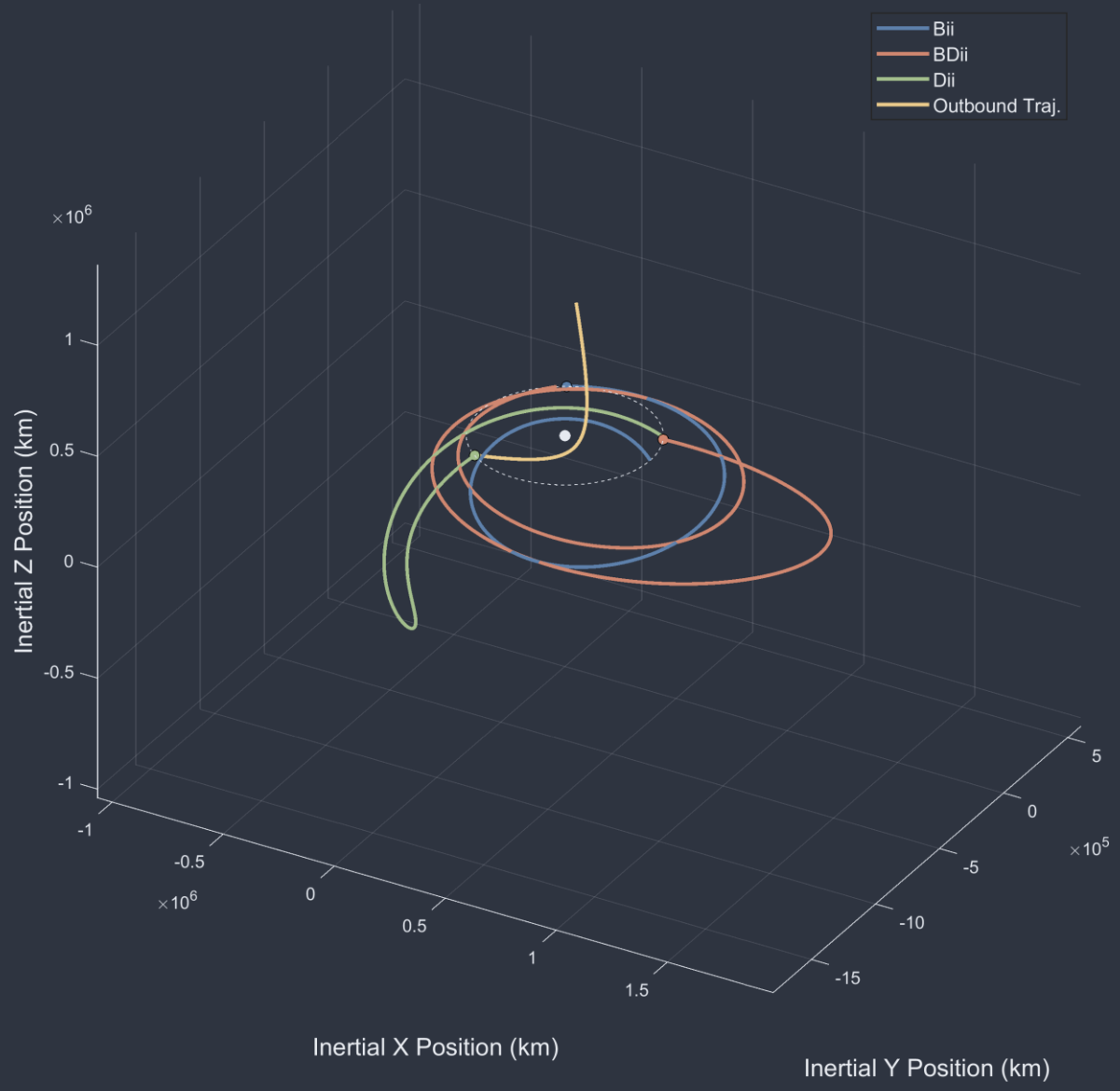
Please join Virtual Room Trajectory Design and Optimization XX on August XX, 2021 at XX:XX AM EST

Thank you

BiiBDiiDii Continued



BiiBDiiDii Continued



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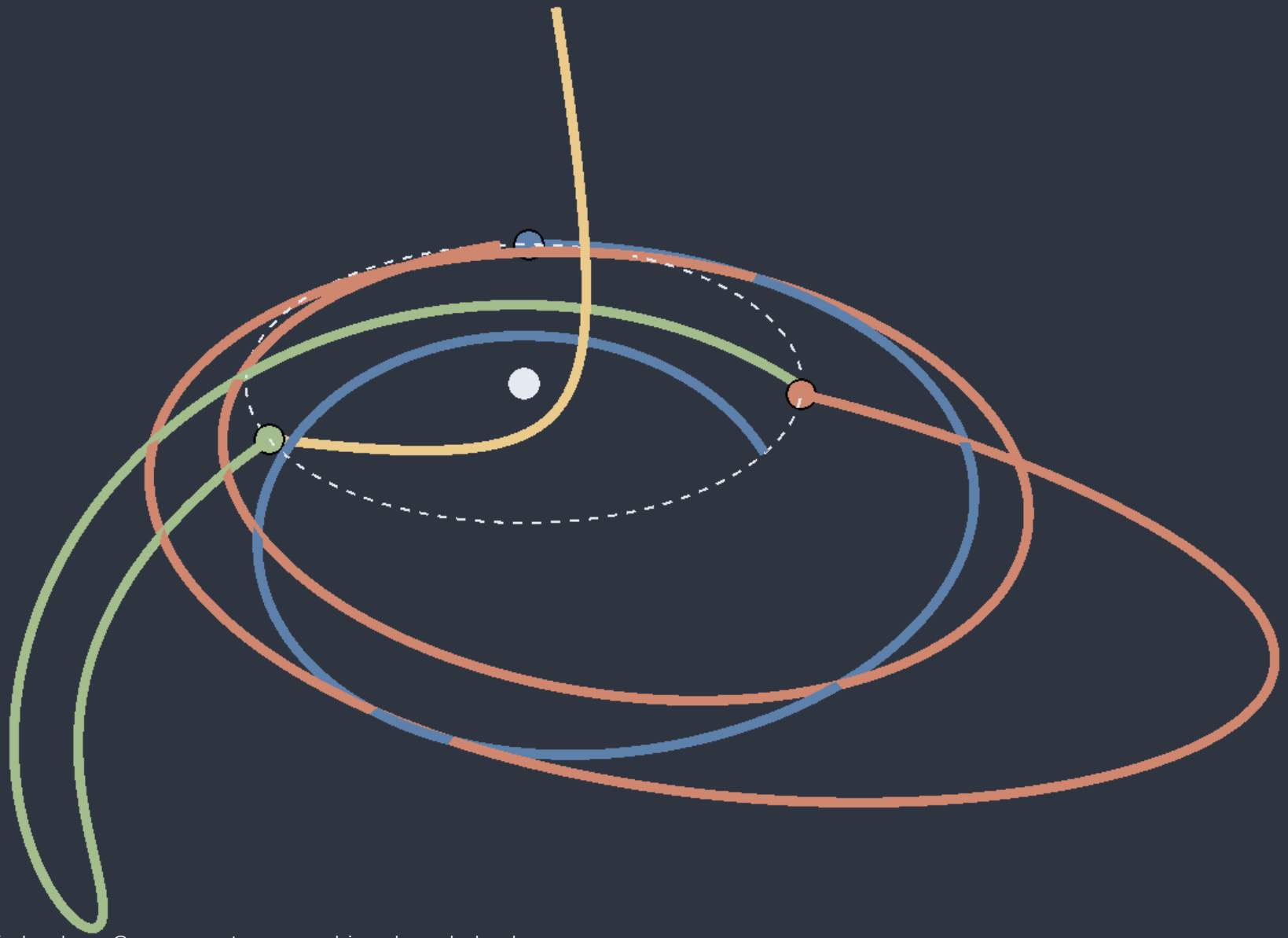
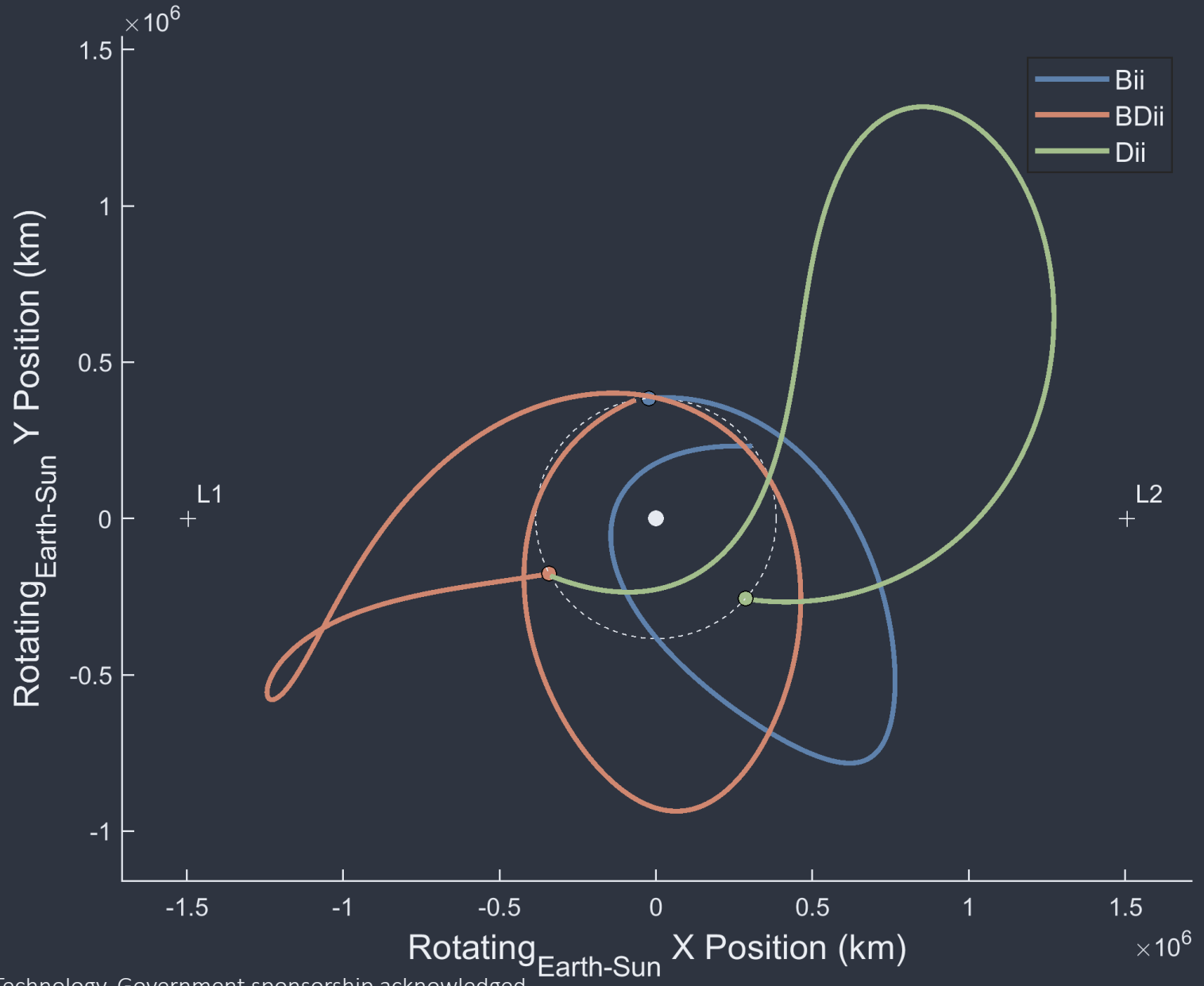
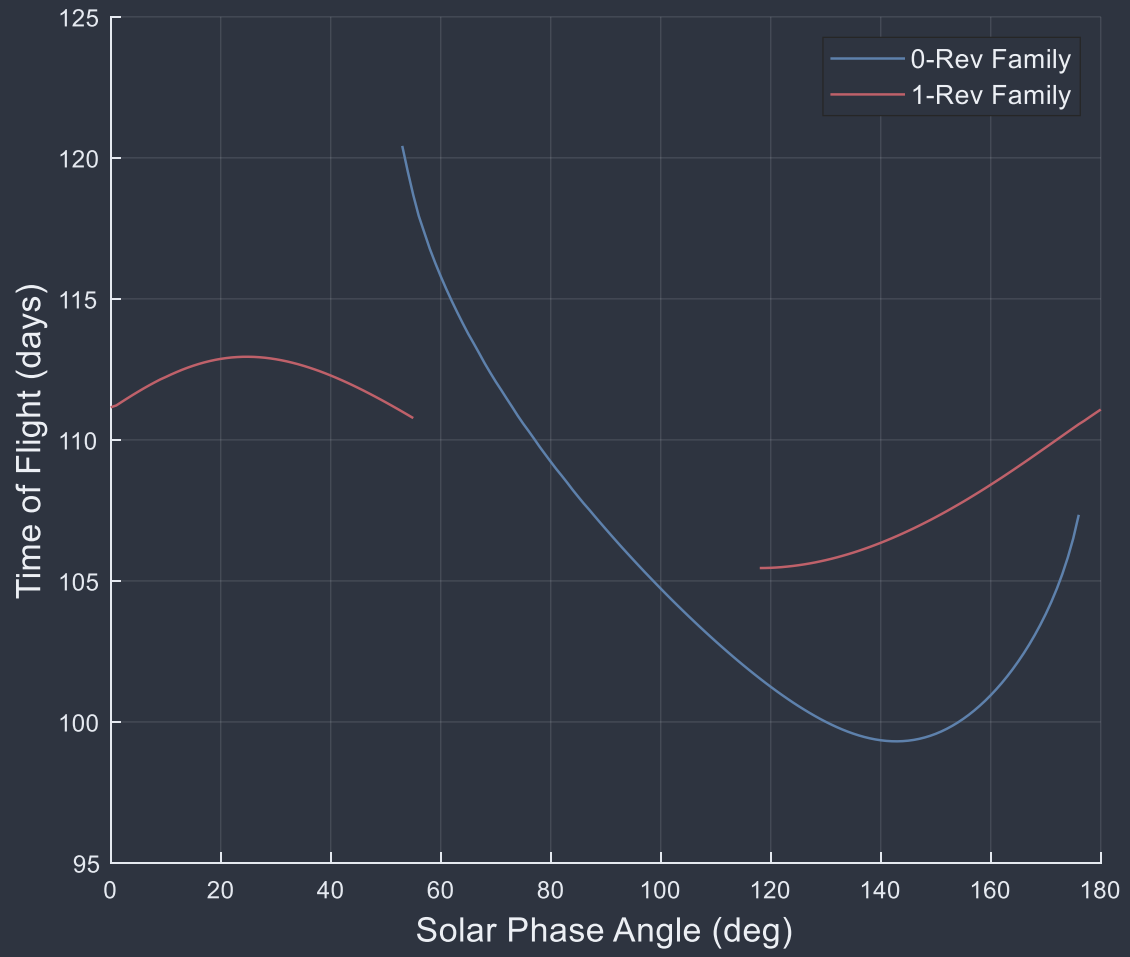


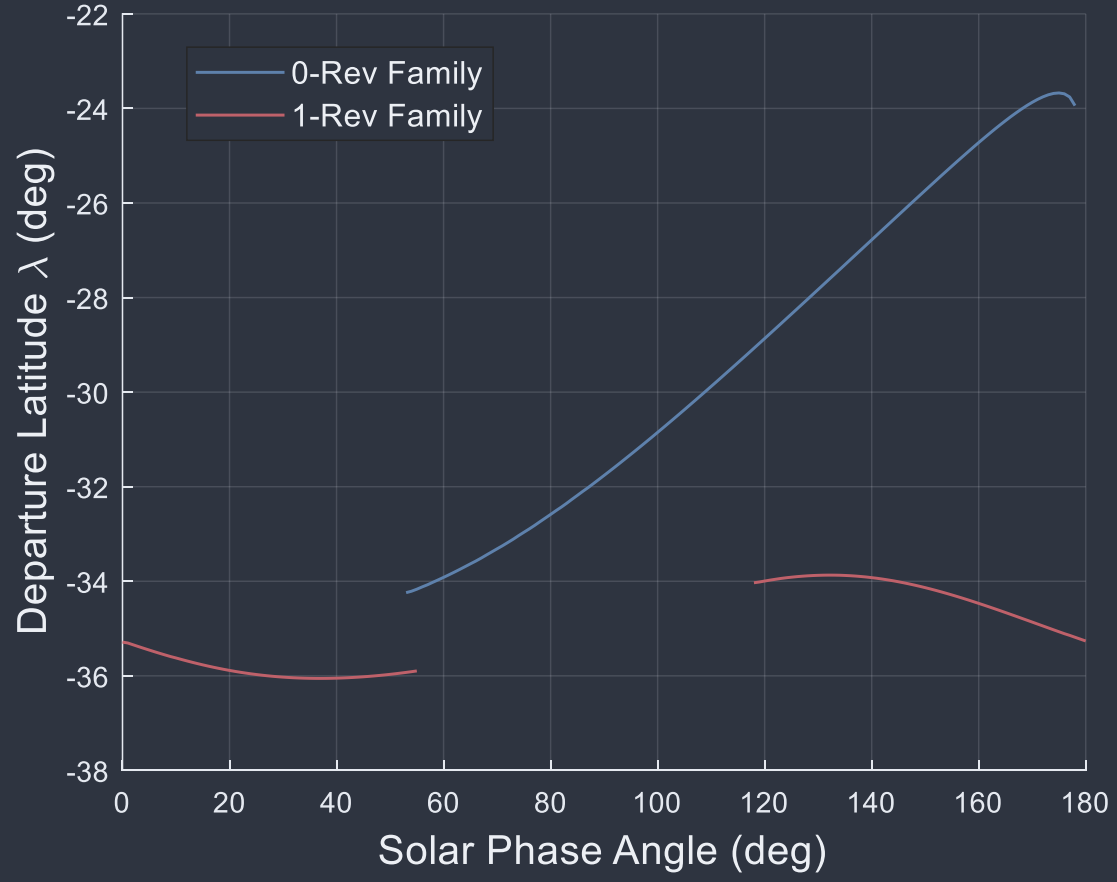
BiiBDiiDii Rotating Frame



1-Rev vs 0-Rev Families

4-Month (D) “ii” Family @ $\vec{v}_\infty$ 1.4 $^{km}/_{s}$





1-Rev vs 0-Rev Families

4-Month (D) "ii" Family @ $\vec{v}_\infty$ 1.4 $^{km}/_{s}$