Optimization of High Inclination Orbits for a Zodiacal Light Imaging Mission

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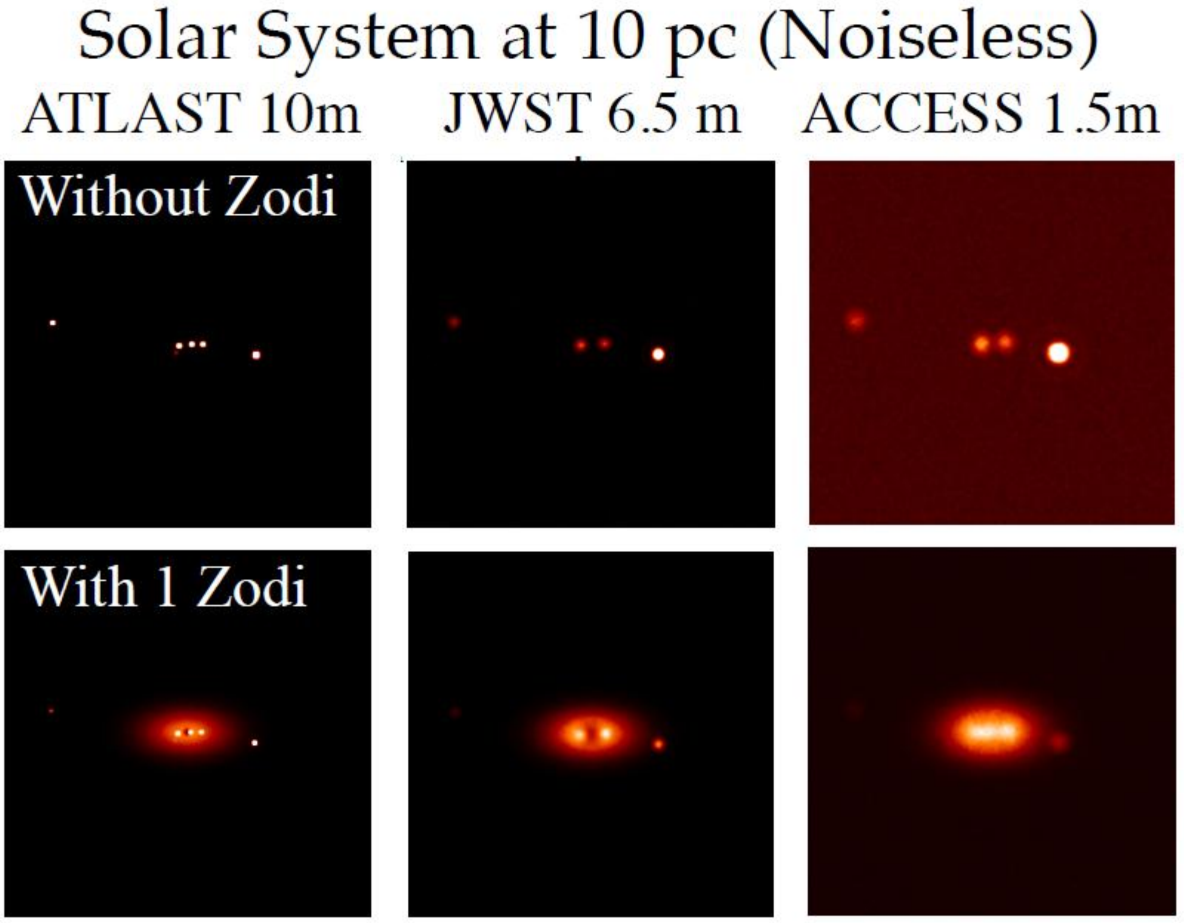
Zodiacal Light

- Caused by interplanetary dust clouds as evidenced from IRAS (1983)
- Second-most luminous source of light
- Lasting structure in our solar system

Photograph by: Damian Peach

Zodiacal Light

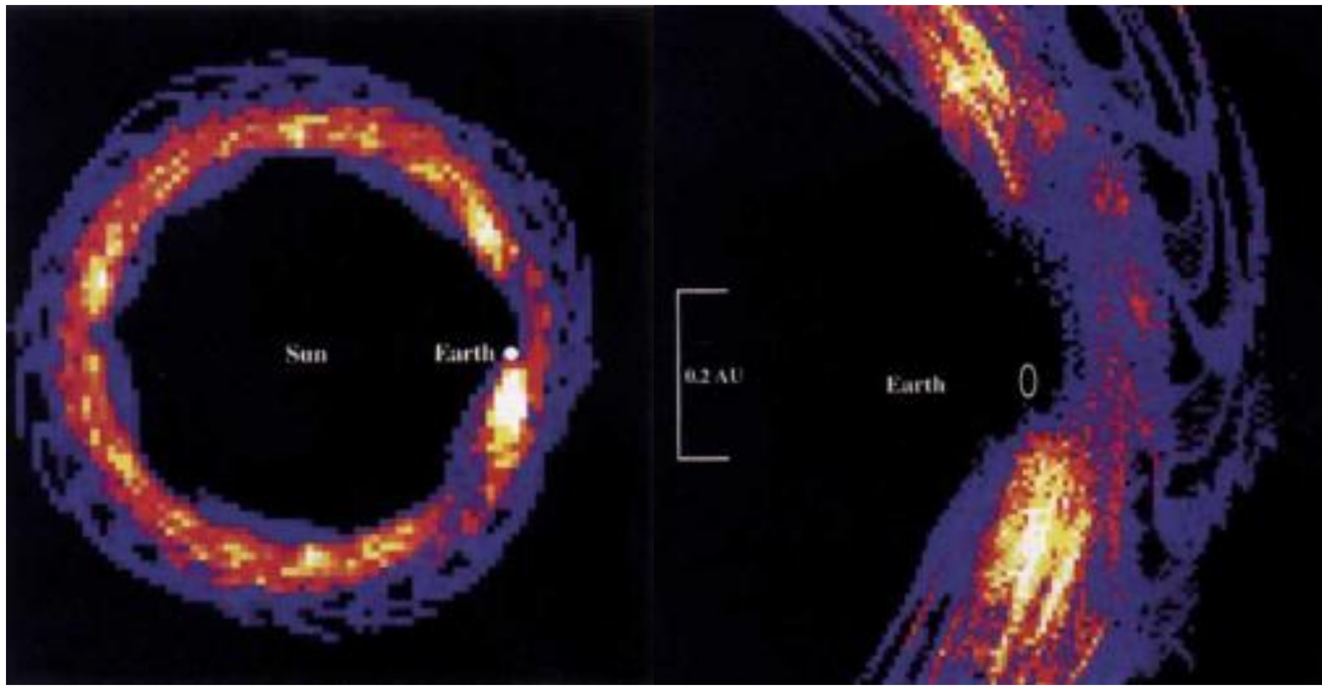
- Spacecraft missions near Earth affected by unknown structure
- Noise from zodiacal light hinders exoplanet searches



Cash, Glassman, Lo & Soummer, SPIE 7731 (2010)

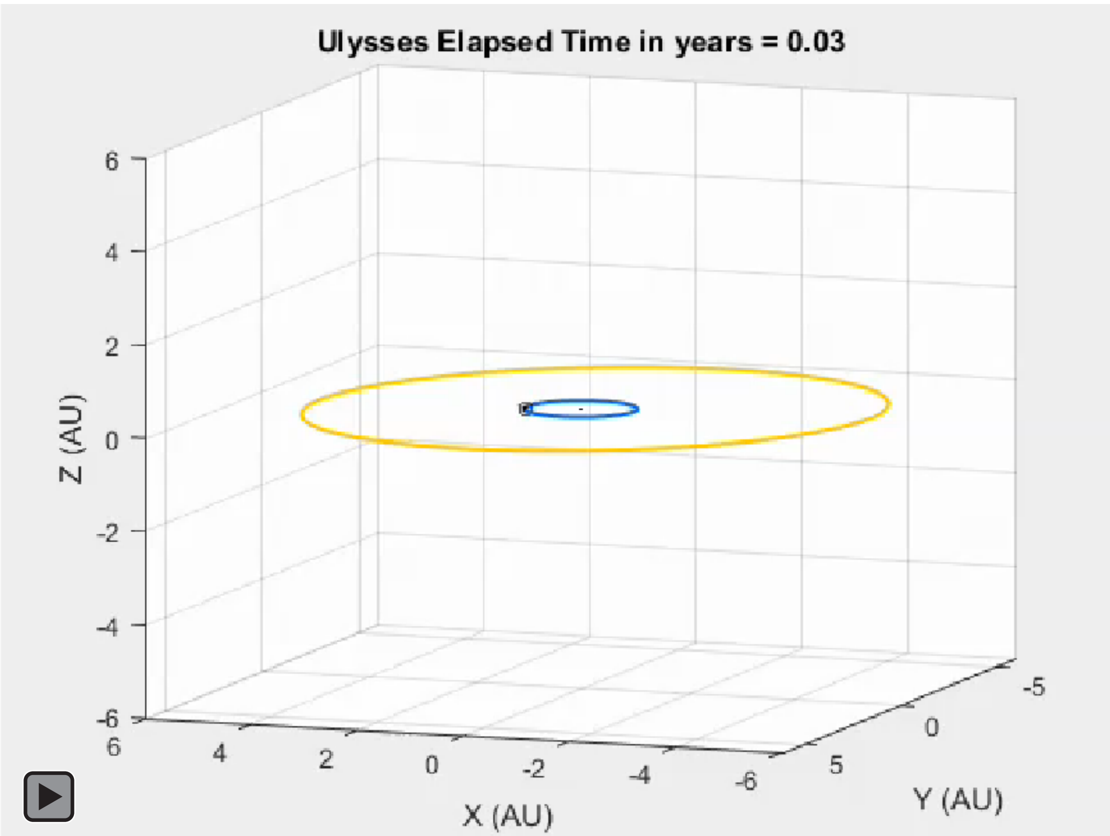
Zodiacal Light

- Dust bands nearly parallel to ecliptic
- Circumsolar rings resonantly locked with Earth



Dermott et al. (1994)

Mission Requirements

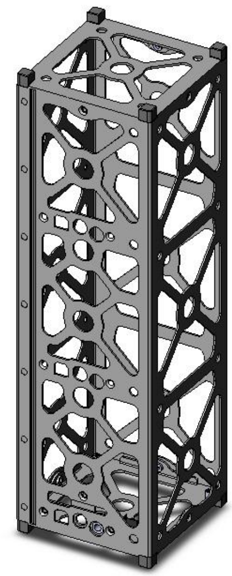


- Zodiacal structures observable from above ecliptic
- Ulysses mission originally had equipment to image the zodiacal light
- Need cost-effective spacecraft

Mission Requirements

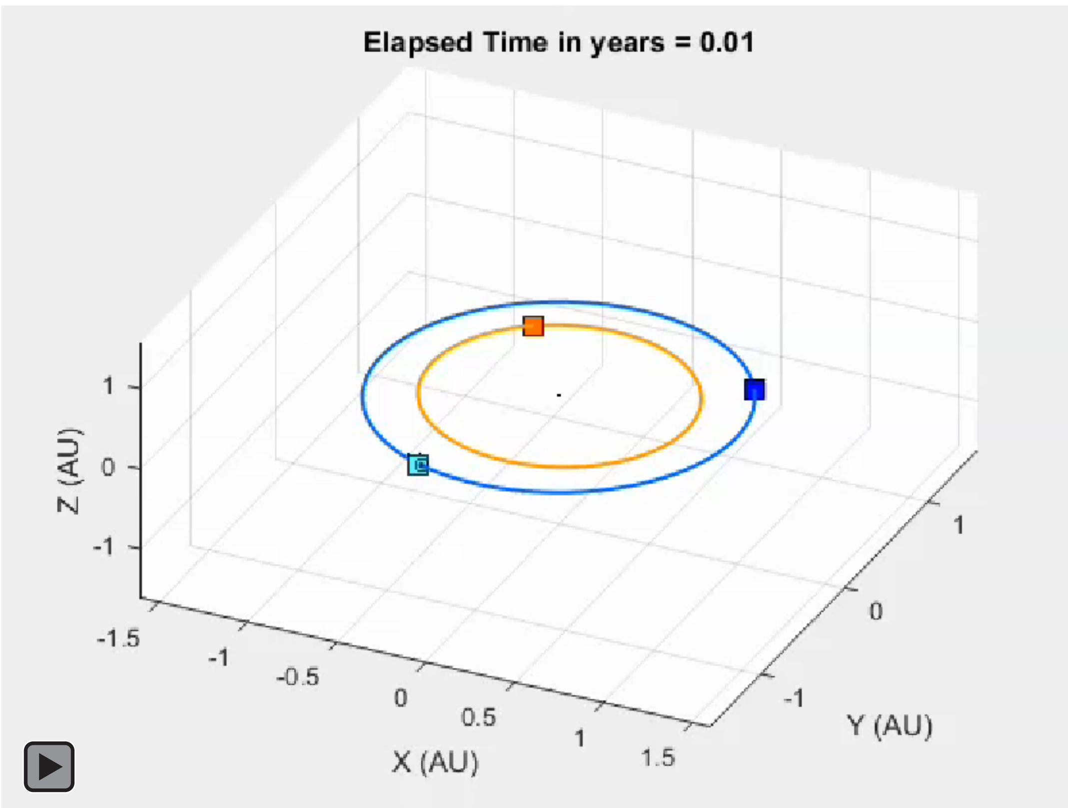
- Minimum orbital height of 0.1AU
- IR/visible light ~3cm camera
- Minimize fuel consumption (ΔV) and mass

- CubeSats currently capable of ~200m/s (VACCO Industries)
    - ~500m/s propulsion units in development (Aerojet Rocketdyne)

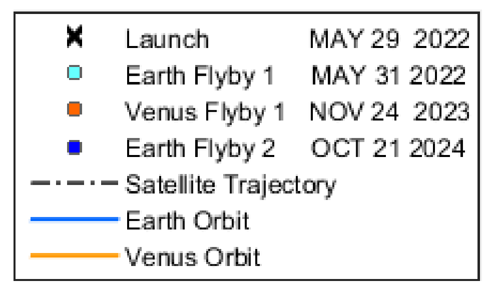


3U CubeSat Kit from Pumpkin Inc.

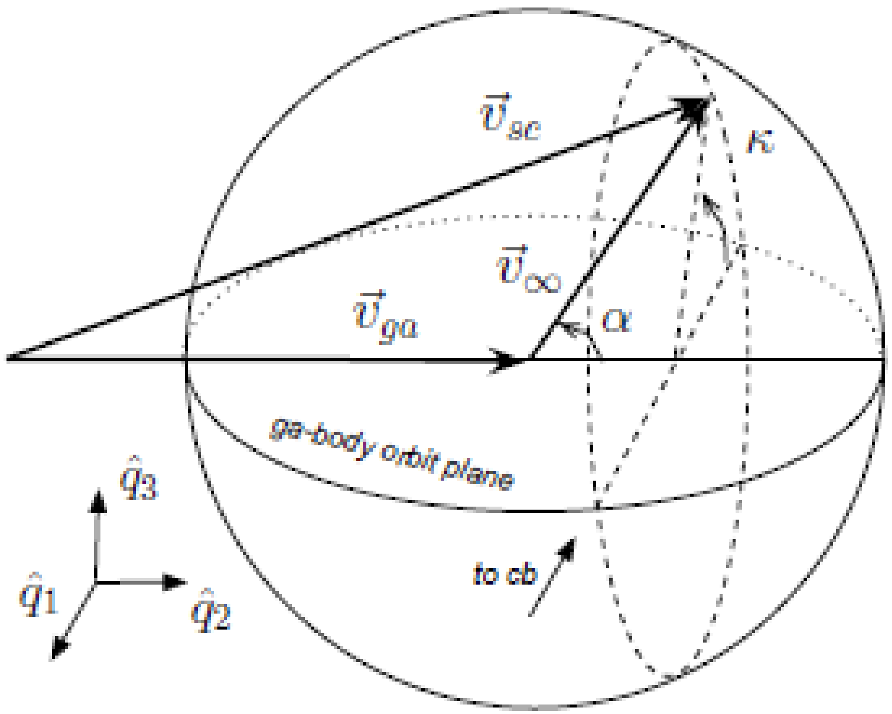
Orbital Considerations



- Potential primary missions to board:
  - Europa Multiple Flyby Mission (2022)
  - Exploration Mission 1 (2018)
- Telecommunications depend on distance from Earth



Orbital Techniques



Russell and Strange (2007)

- V-infinity sphere
  - Magnitude determined by orbit before flyby
- Two parameters in a 3-D flyby: pump and crank angles
  - Pump (α) widens orbit
  - Crank (κ) inclines the orbit

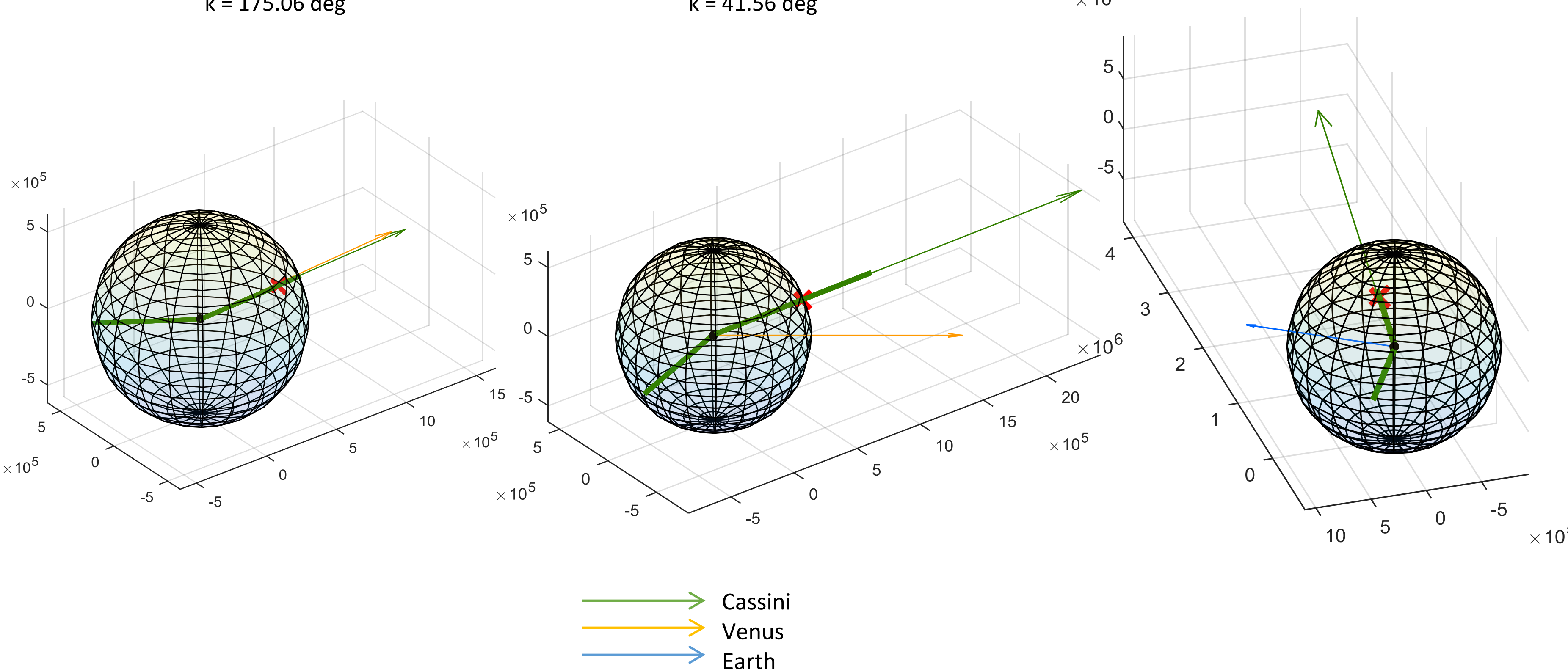
Orbital Techniques

- Cassini Example: Inner Planetary Flyby Schedule

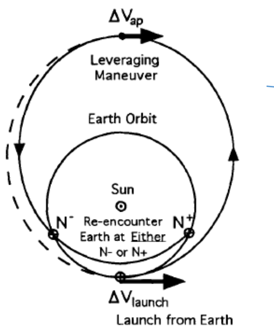
Venus Flyby 1
α = 1.03 deg
κ = 175.06 deg

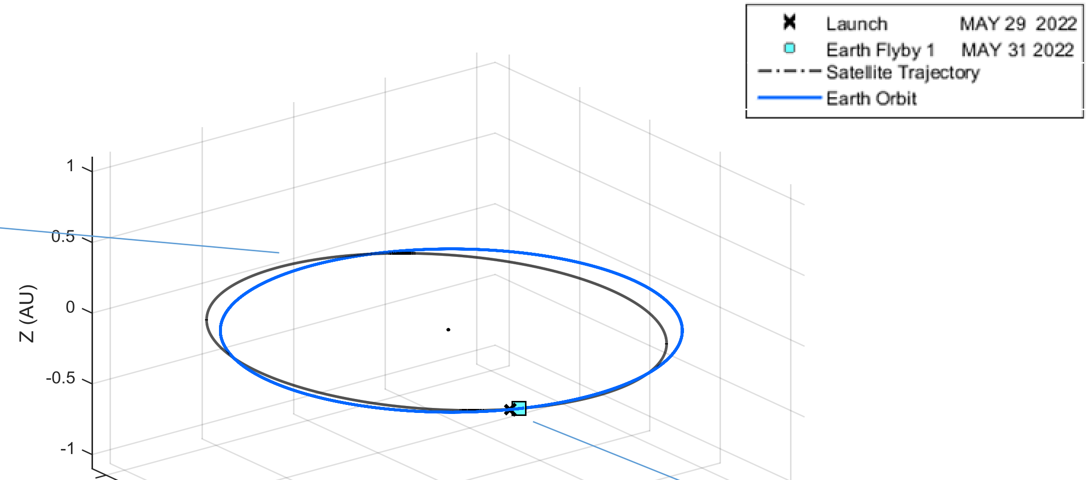
Venus Flyby 2
α = 22.29 deg
κ = 41.56 deg

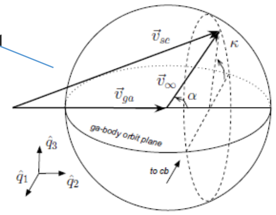
Earth Flyby 1
α = 64.92 deg
κ = 178.08 deg



Optimization Problem

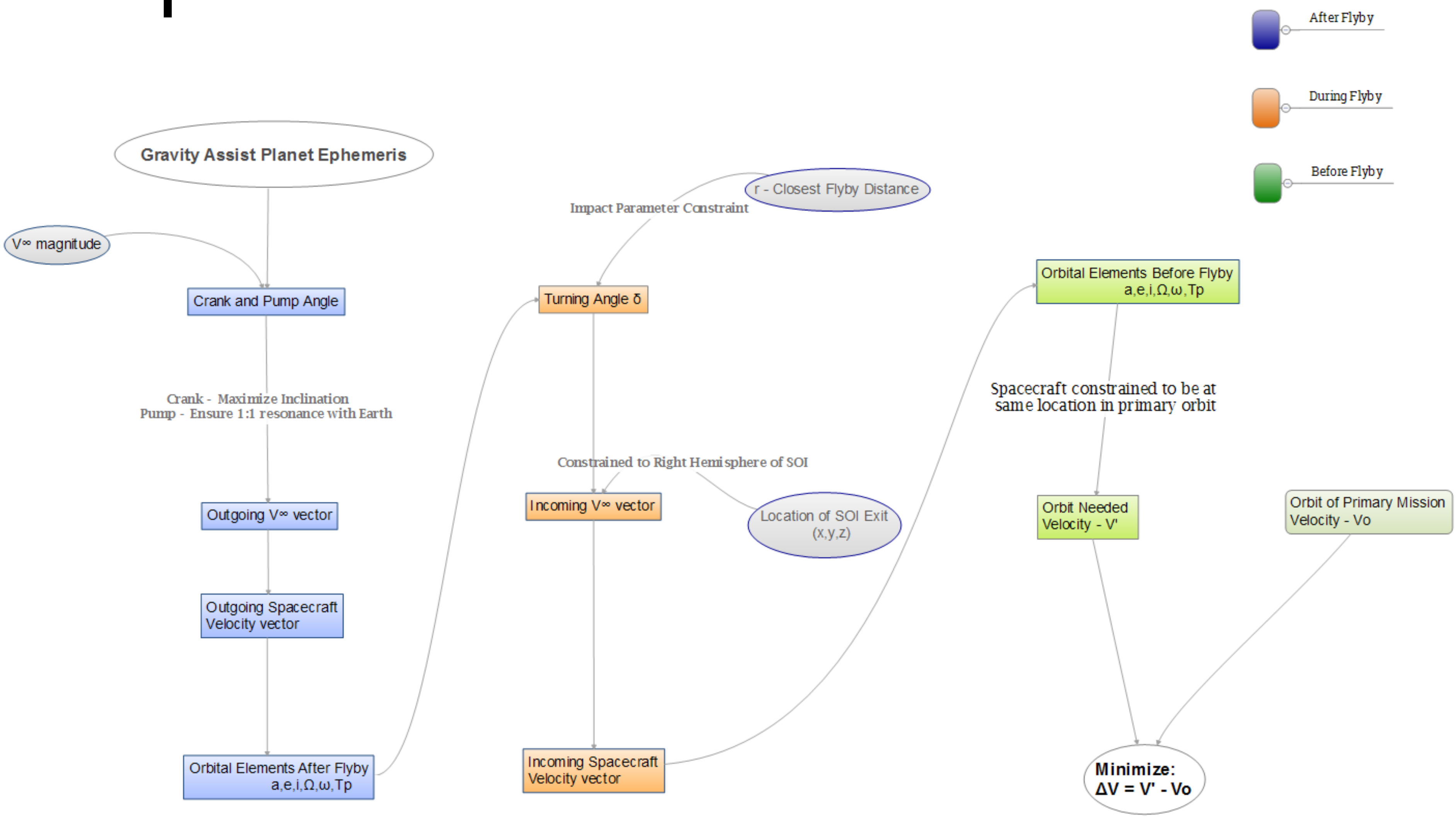






- SNOPT: Sparse Nonlinear Optimizer
- Minimize amount of Δv needed to achieve orbit wanted
  - Maximize inclination with crank angle
  - Maintain resonance with pump angle

Optimization Problem



Future Work

- Apply to 2022 Europa Mission (Atlas V)
  - Determine if one flyby is sufficient
- Test with different planetary flybys
  - Lunar
  - Jupiter
  - Earth-Venus-Earth
- Propulsion and structural design of spacecraft

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References

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