Seasonal Variations of the James Webb Space Telescope Orbital Dynamics

AAS 15-802

Jonathan Brown (a.i. solutions)
Jeremy Petersen (a.i. solutions)
Benjamin Villac (a.i. solutions)
Wayne Yu (NASA GSFC)
Agenda

• Introduction
• Injection States
• CR3BP Explanation
• Matching Orbits in the CR3BP
• Conclusion
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Introduction

Planetary systems and the origin of life

End of the dark ages: First light and reionization

The assembly of galaxies

Birth of stars and proto-planetary systems

Planetary systems and the origin of life

Image credit: http://jwst.nasa.gov/observatory.html
Representative JWST Orbit

**Event** | **Time After LV Sep.**
--- | ---
MCC-1a | 12 hours
MCC-1b | 2.5 days
Sunshield Deployment | 5.5 days
MCC-2 | 30 days

**Maneuver** | **ΔV Budget (m/s)**
--- | ---
MCC-1a | 41
MCC-1a Late | 8
MCC-1b | 7.5
MCC-2 | 5
Margin | 5
Total | 66.5

Operational Orbit Constraints
RLP Y: ±832,000 km (130 Re)
RLP Z: ±532,000 km (83 Re)
Vastly different orbits depending on launch time

01 Oct 2018  13:10 UTC
25 Nov 2018  12:45 UTC
27 May 2019  13:15 UTC
Variation in Orbit Geometry

Launch Epoch (UTC)
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Launch Separation States

Separation state is constant in ECEF

30 days

11:30 UTC

14:00 UTC
Variation in Orbit Geometry

Launch Epoch (UTC)
Variation in Orbit Geometry

Launch Epoch (UTC)
Variation in Orbit Geometry

Launch Epoch (UTC)

Lissajous

Halo

Lunar Blackout
Variation in Orbit Geometry

Launch Epoch (UTC)

October 2018

Lissajous

Quasihalo

Halo

Quasihalo

Lunar Blackout

Quasihalo

Quasihalo

Quasihalo
Post-MCC-1a State

RLP position RA and DEC variation with time

Launch epoch (days past Oct. 10, 2018)

RLP position RA-DEC curves

RLP velocity RA-DEC curves
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Sample Periodic Orbits in the CR3BP

- Northern Halo - Southern Halo
- Vertical - Lyapunov
* L2 * Earth
Stable Manifold
Near Ballistic Transfer

Nominal 3 MCC
Single MCC 100%
Single MCC 95%
No Burn
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Manifold Intersection with Injection
Matching States with Halo Manifolds

- Find injections states that intersect with halo manifolds in 4D
- Orbit amplitudes from CR3BP match trajectory in full ephemeris model
Matching States with Periodic Manifolds

Southern halo
Northern halo
Lyapunov
Vertical
Matching States with Periodic Manifolds

- Southern halo
- Northern halo
- Lyapunov
- Vertical
Matching States with Periodic Manifolds

Injections states closest to Lyapunov result in Lissajous

Southern halo
Northern halo
Lyapunov
Vertical
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Conclusion

• LV separation state is fixed ECEF, so inertial states vary with hourly, daily, monthly, and yearly frequencies

• The net effect of all frequencies leads to significant variations in orbit geometry

• Injection states can be matched with invariant manifolds of periodic orbits in the CR3BP to explain observed final orbit
Thank You

Image credit: http://jwst.nasa.gov/images_jwst.html