A faint, light blue wireframe illustration of the James Webb Space Telescope, showing its large segmented primary mirror, secondary mirror, and the long sunshield structure.

James Webb Space Telescope Launch Window Trade Analysis

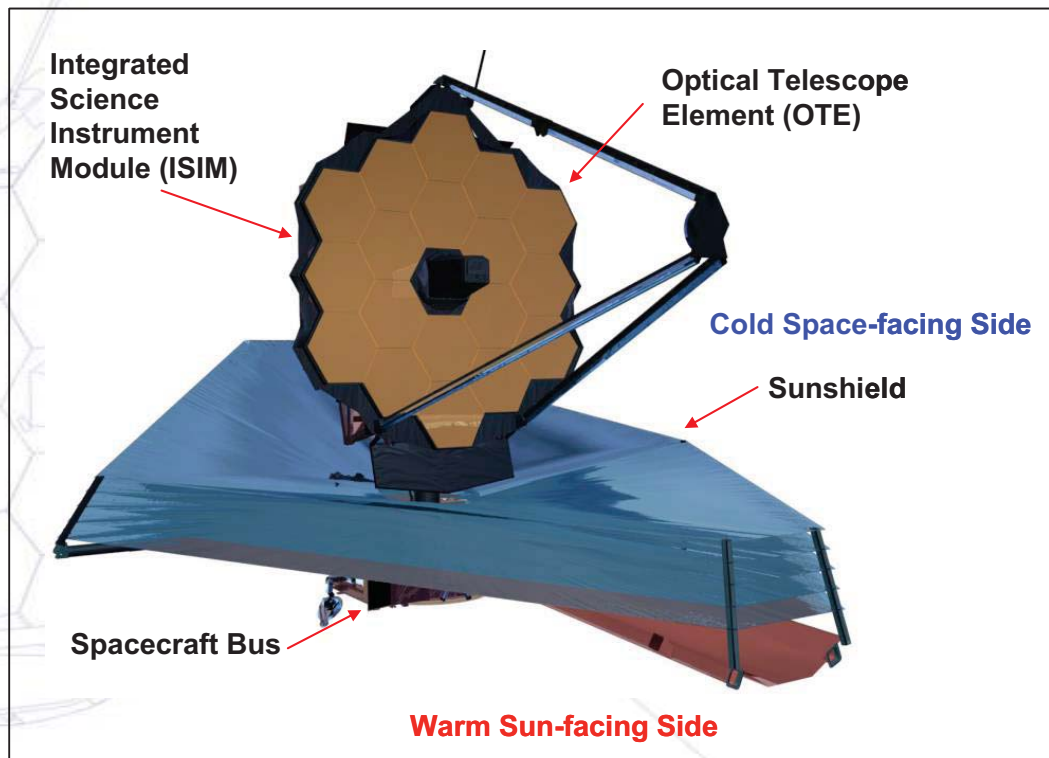
**Wayne Yu (NASA GSFC)
Karen Richon (NASA GSFC)
5 May 2014**

**24th International Symposium on Space Flight Dynamics (ISSFD)
Laurel MD**

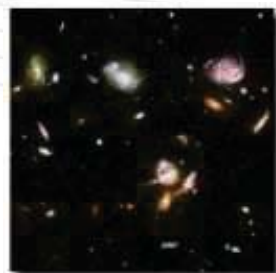


- **Introduction**
- **Overview of the James Webb Space Telescope**
- **Trajectory Design Requirements on Launch Window**
- **Unconstrained Launch Window**
- **Partially Constrained Launch Window**
- **Fully Constrained Launch Window**
- **Conclusions / Future Work**

- James Webb Space Telescope (JWST) is a deployable infrared telescope
- Orbit design is a Sun-Earth/Moon L2 Libration point orbit
- Nominal Launch Readiness Period: October 1st 2018 – Nov 30th 2018
 - This presentation studies the launch window in October 2018 from 11:30 – 14:00 UTC
- 10.5-year science mission goal



JWST Science Themes



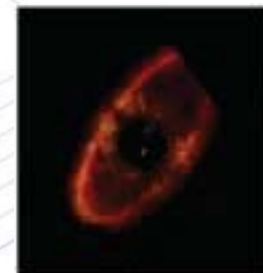
End of the dark ages: First light and reionization



The assembly of galaxies



Birth of stars and proto-planetary systems



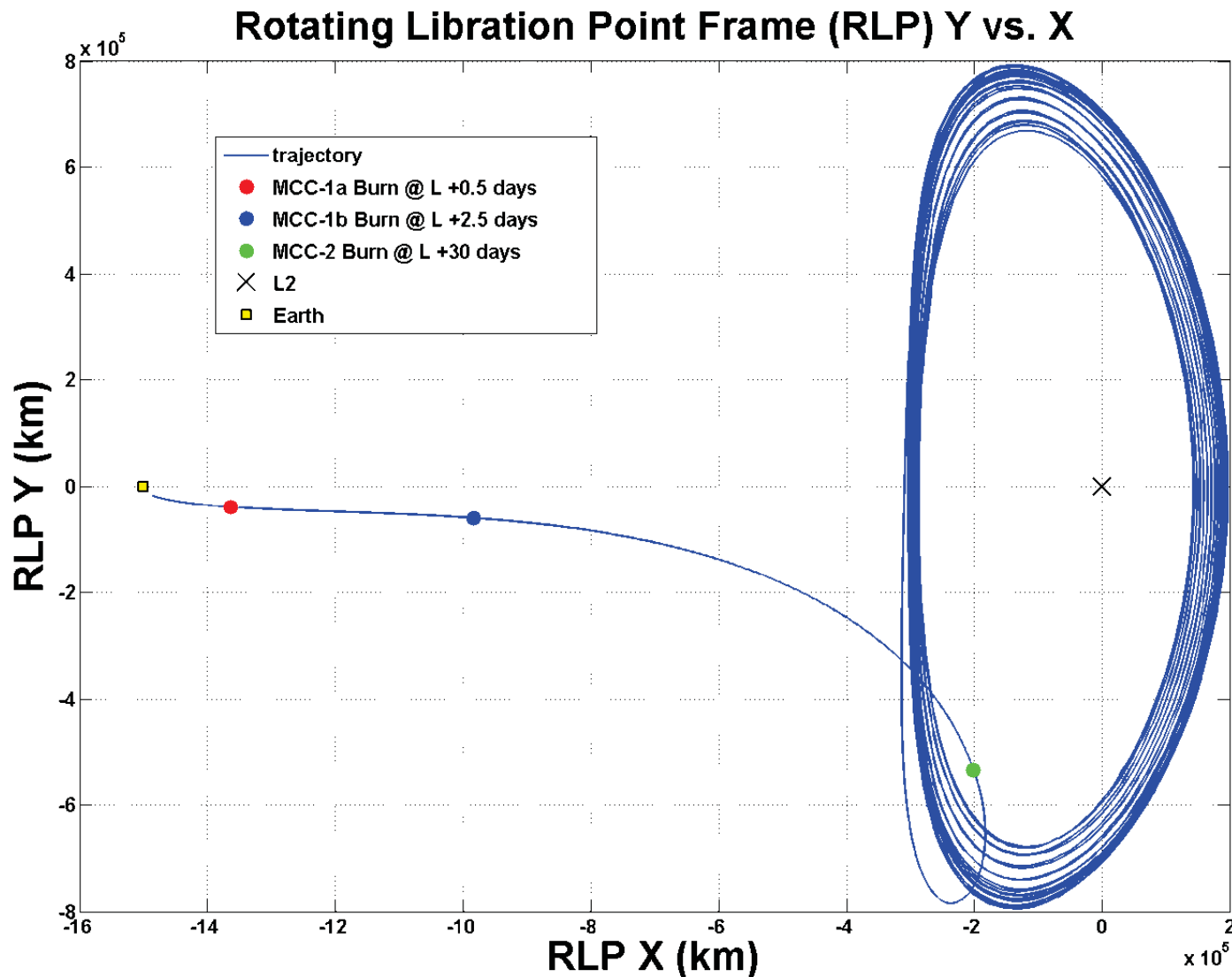
Planetary systems and the origin of life

What is the launch window that satisfies JWST subsystem derived constraints?

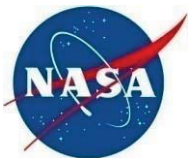
- European Space Agency-supplied Ariane 5 with the launch site at Kourou, French Guiana
- Injects JWST into a highly elliptical orbit with one of the given apogee altitudes below
- By design, energy from launch vehicle is not enough to achieve desired orbit
- JWST will perform three mid-course correction (MCC) maneuvers to transfer to the L2 libration point orbit

Designation	Apogee Altitude provided	C3 Energy Provided
Flight Program 1(FP1)	$1.02 * 10^6$ km	$-0.7665 \text{ km}^2 / \text{s}^2$
Flight Program 2(FP2)	$1.06 * 10^6$ km	$-0.7381 \text{ km}^2 / \text{s}^2$
Flight Program 3 (FP3)	$1.10 * 10^6$ km	$-0.7117 \text{ km}^2 / \text{s}^2$

The Ariane 5 vehicle can provide any of the three initial orbital energies for a given launch epoch to compensate for non-optimal launch times and dates



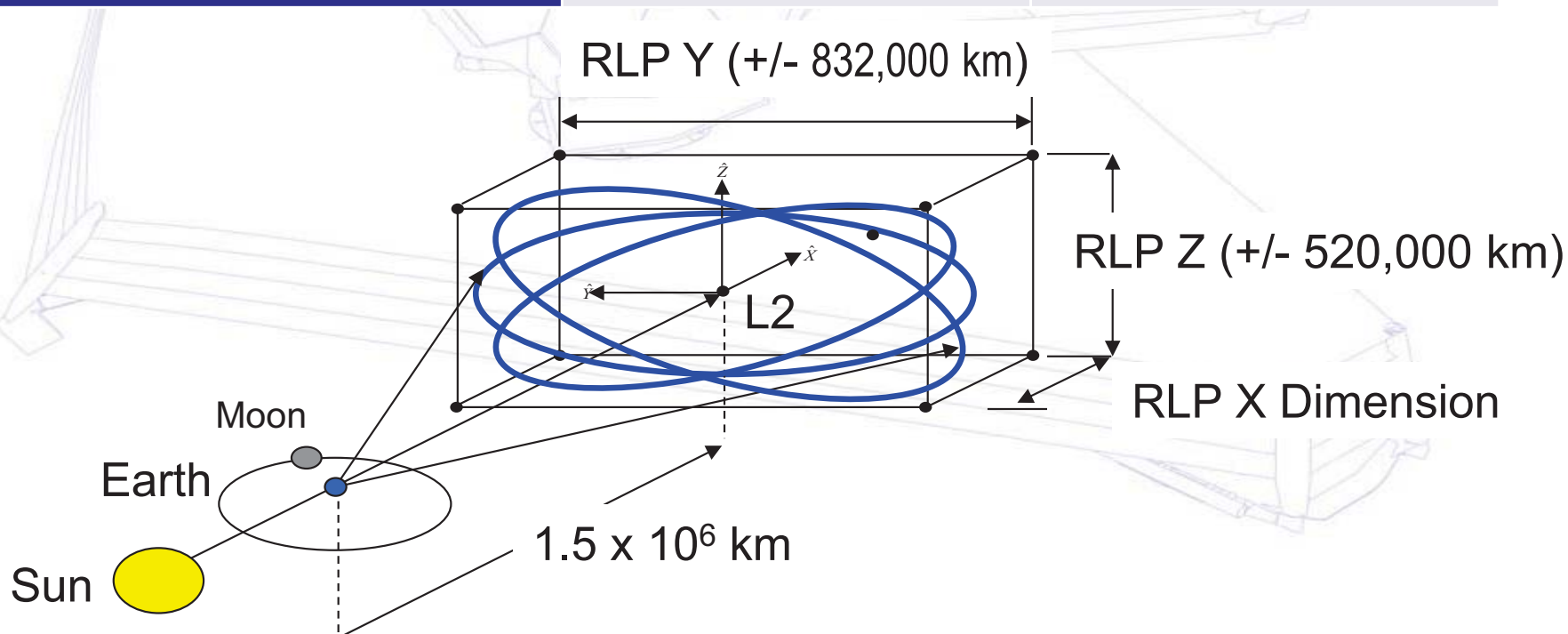
Three mid-course correction (MCC) maneuvers add to the launch vehicle's provided orbital energy so JWST will naturally fall into the Sun-Earth/Moon L2 Libration point orbit.

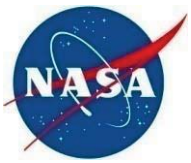


Trajectory Design Requirements Affecting the Launch Window



Requirement/Constraint	Value	Requirements/ Constraint Driver(s)
MCC Maneuver Direction	RLP +X direction	Science
Available Mid-Course Correction (MCC) Maneuver ΔV for Nominal Injection	20.5 m/s - 38 m/s	Mass & Propulsion
Lunar / Earth Eclipse	None allowed	Power and Thermal
Rotating Libration Point (RLP) Size Requirements	See below	Science & Communication

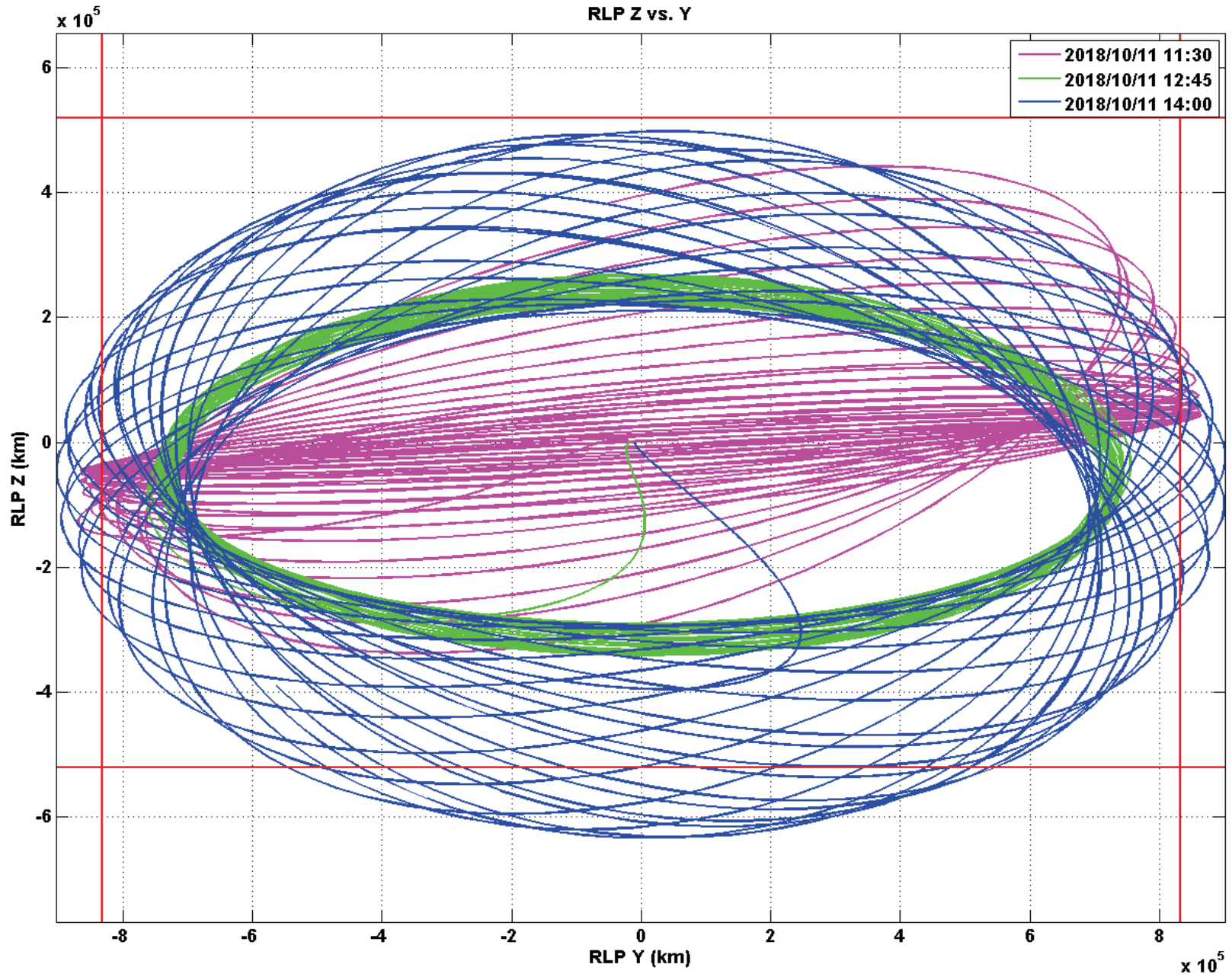


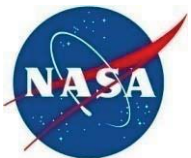


JWST Libration Point Orbit Trajectories: Daily Behavior



Over a single launch day, the JWST orbit launch time is critical to its success. The allowable daily launch window exists within the launch window trade space of 11:30 – 14:00 UTC.





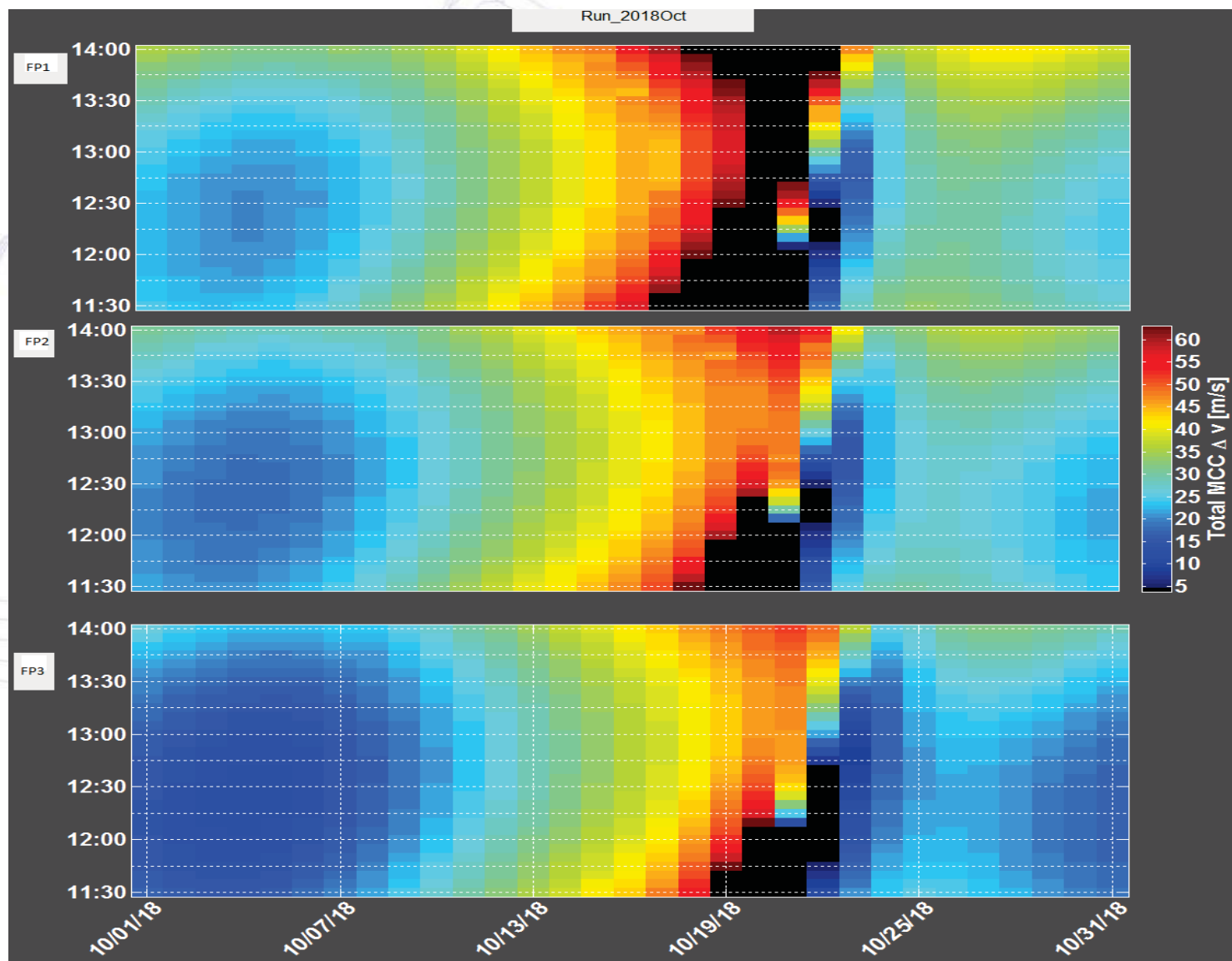
Unconstrained Launch Window October 2018

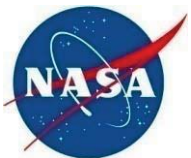


No Constraints

All Three Launch Flight Programs
FP1: Launched to a Lower Apogee
FP2: Launched to the Middle Apogee
FP3: Launch to the Higher Apogee

X Axis: Launch Date
Y Axis: Launch Time (UTC)
Heat Color: MCC Total ΔV Costs



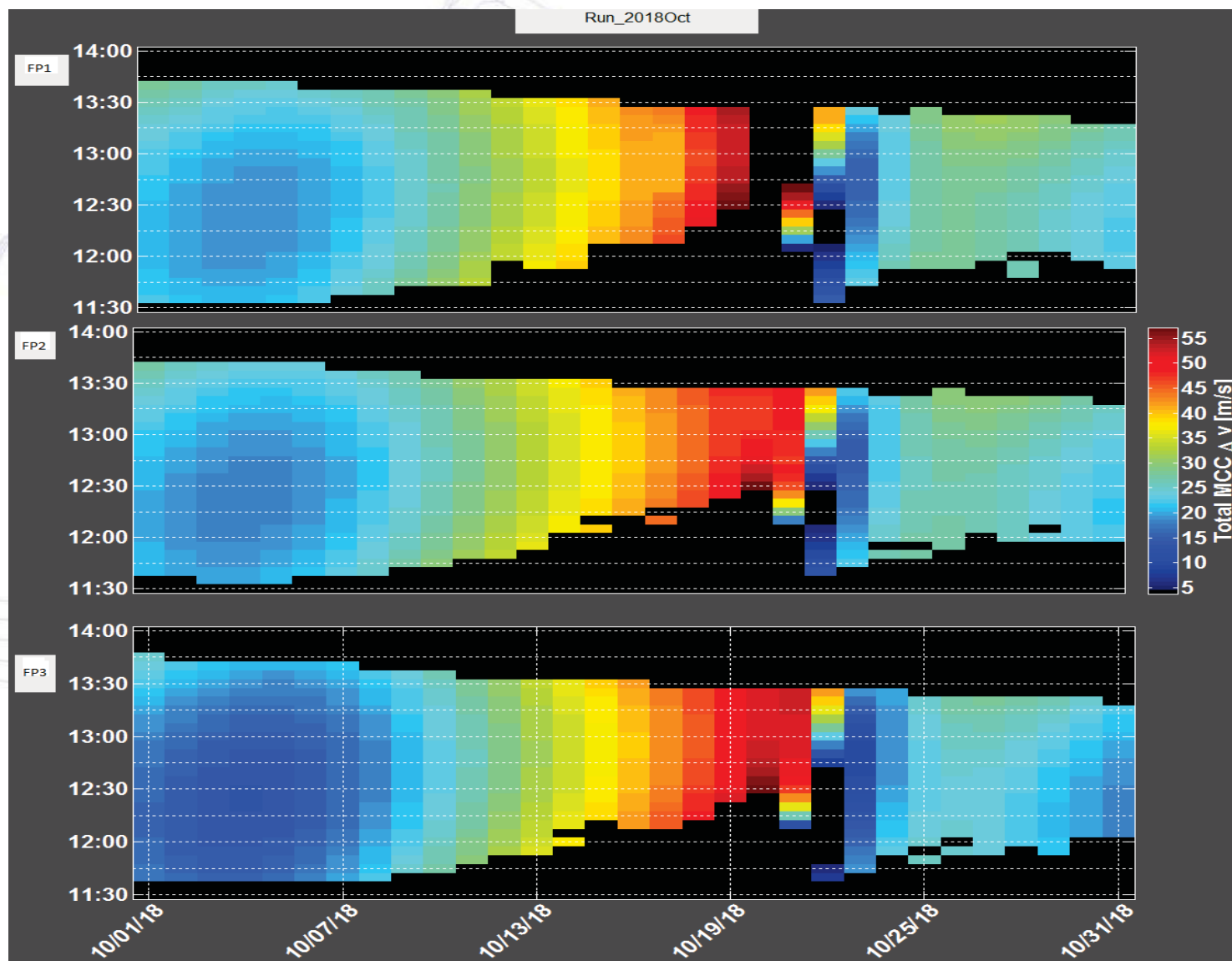


Constrained Launch Window October 2018 (1/3)



Enforced LPO Orbit Size Constraint Only

The LPO Size Constraint removes launch opportunities that are early and late in each launch day.



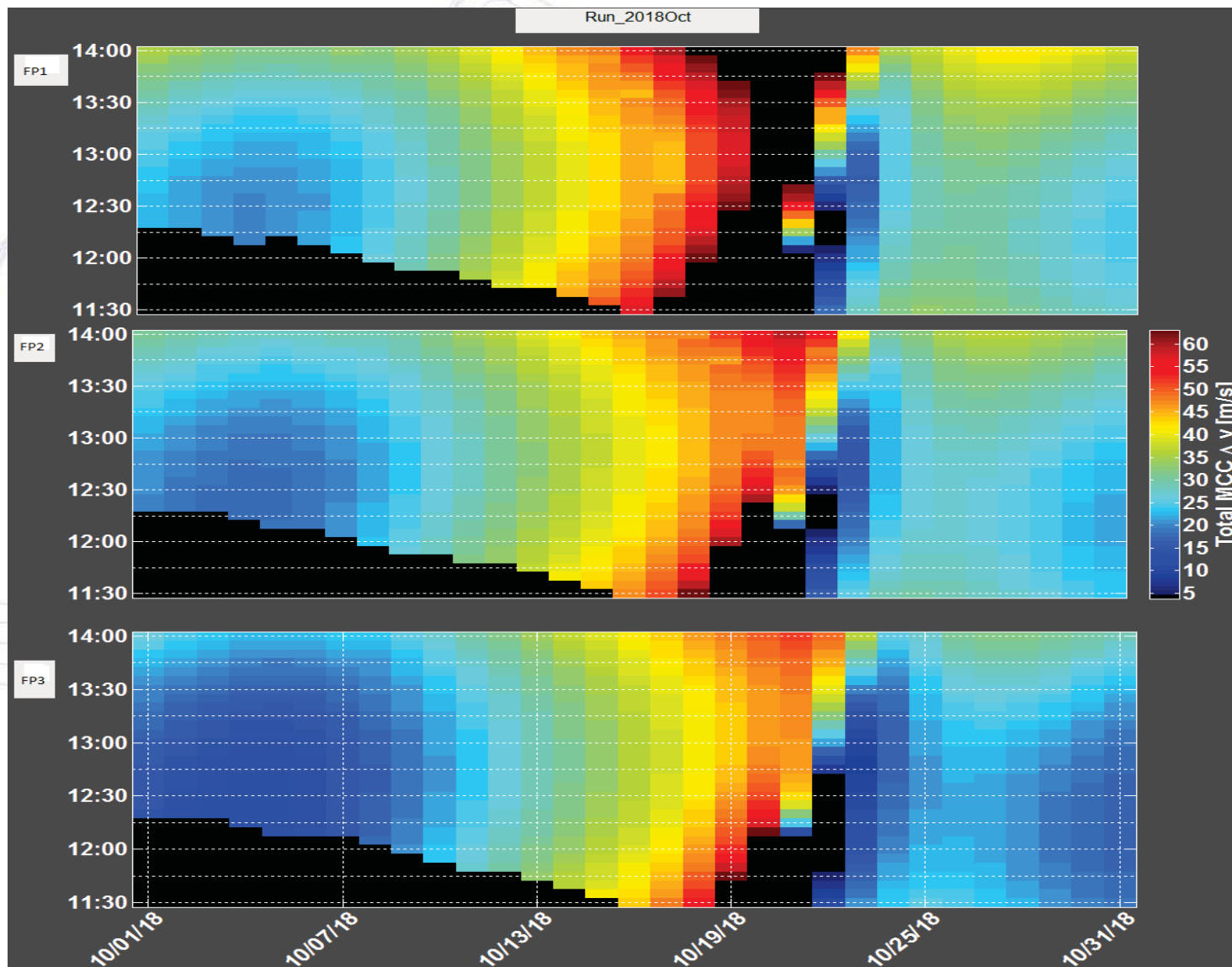


Constrained Launch Window October 2018 (2/3)



Enforced Earth/Moon Eclipse Constraint Only

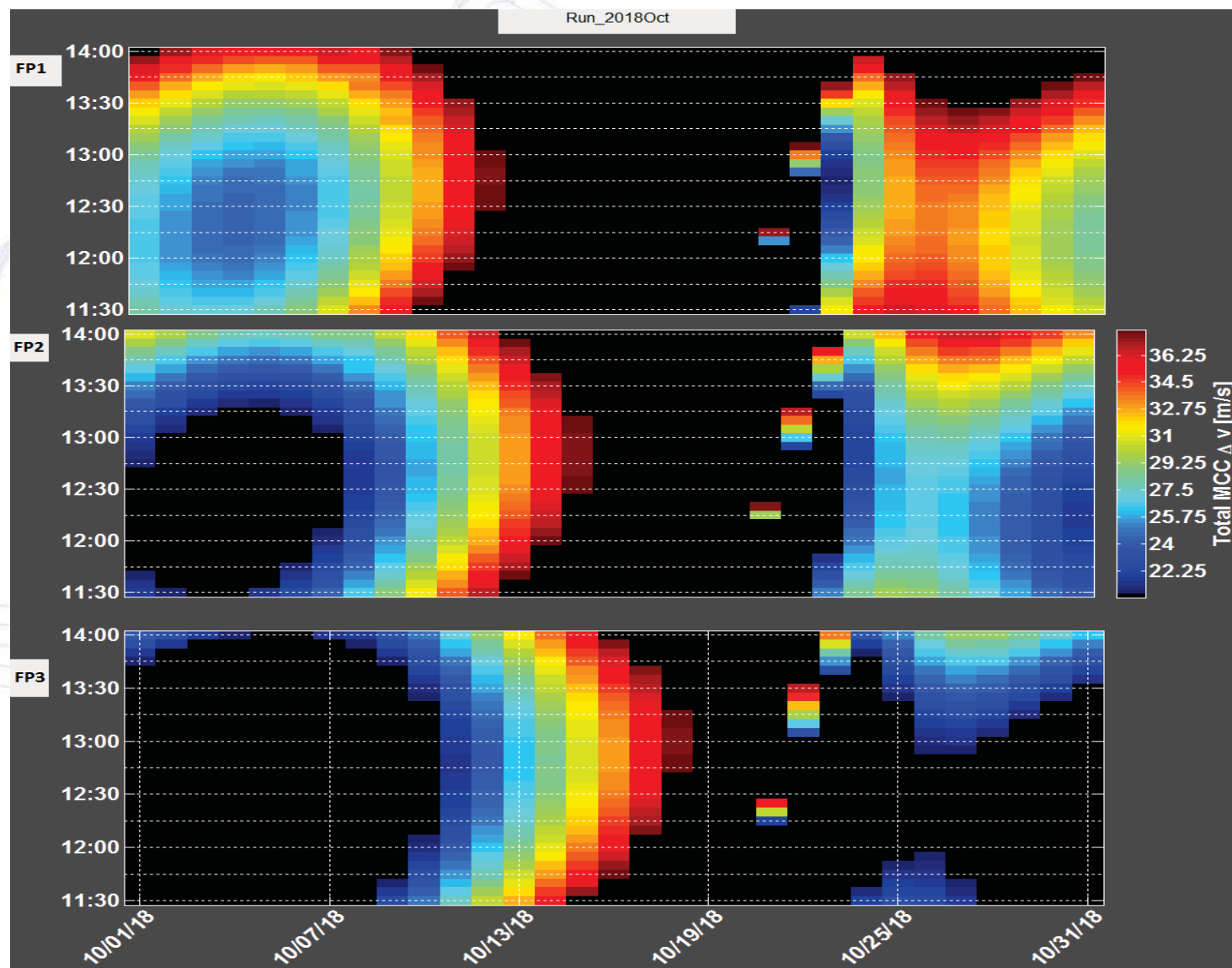
The Earth/Moon Eclipse Constraint removes launch opportunities that are early launch times in early October 2018.

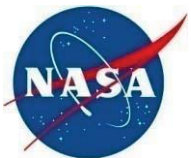


Enforced ΔV Constraint Only

The MCC ΔV upper limit constraint holds back launch opportunities between the first lunar quarter to the full moon.

The Heat Color is rescaled to represent the range of MCC ΔV cost.



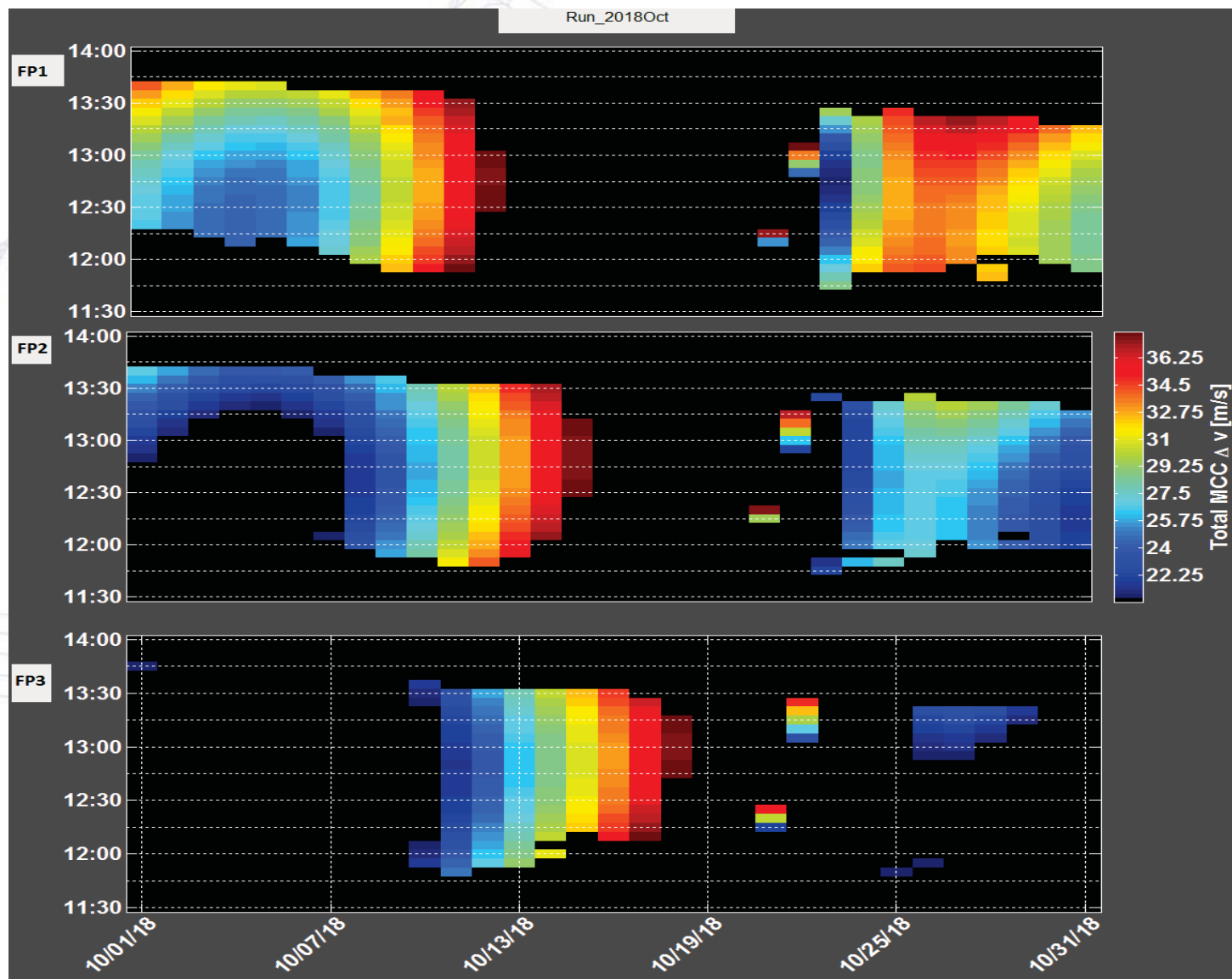


Fully Constrained Launch Window October 2018

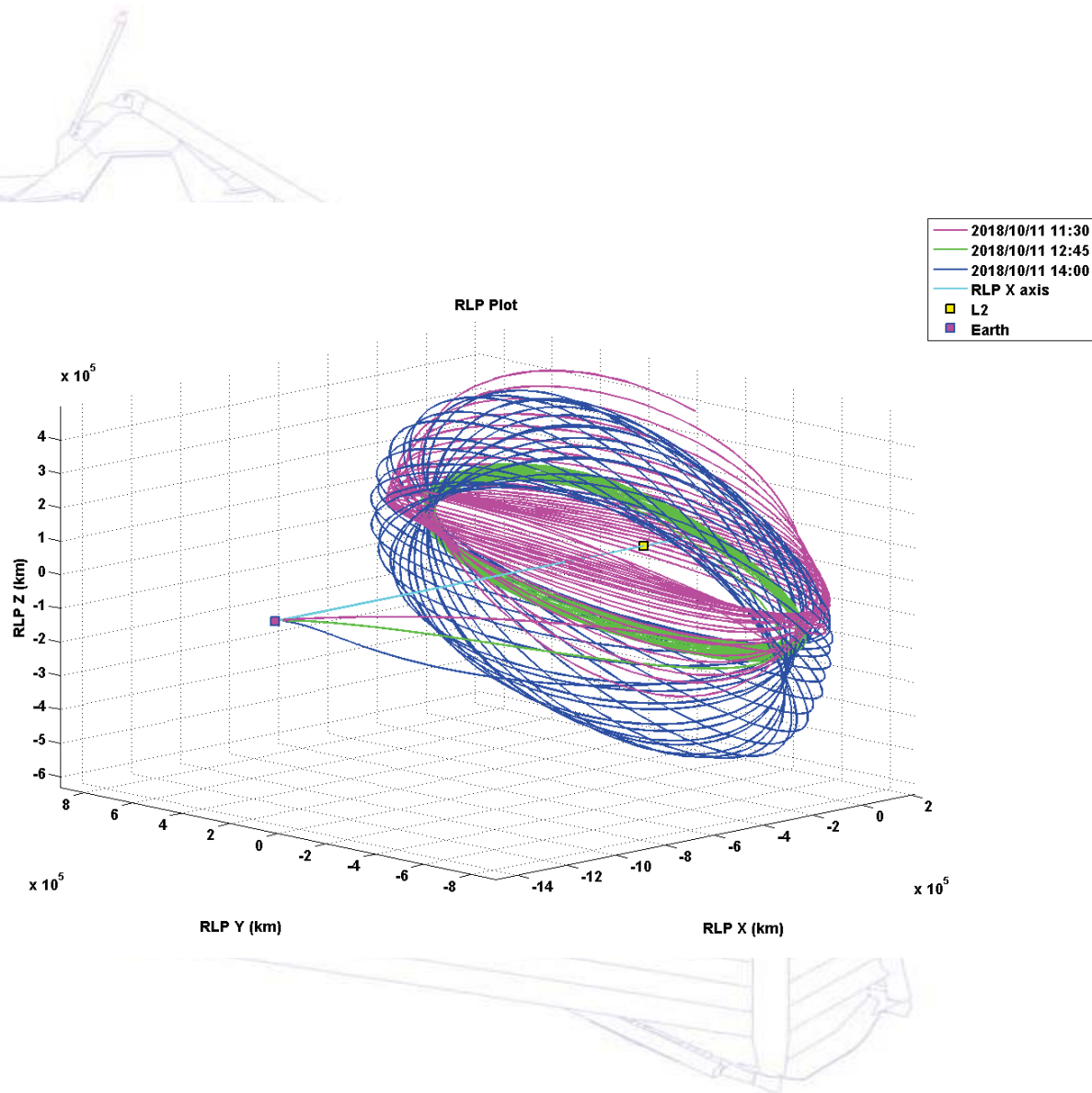


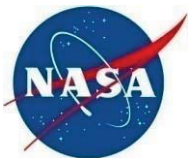
Enforced All Constraints

Only two days within October 2018 do not provide any launch window between all 3 flight programs.



- JWST trajectory design using three MCCs provides a robust launch window for October 2018.
- By utilizing all three Ariane 5 FPs, a daily window of at least 1 hour is possible for 26 out of 31 launch days.
- The span of daily launch times result in significantly different LPO types and sizes, which may satisfy or violate requirements.
- Future Work includes refining these results with higher-fidelity modeling of launch vehicle dispersion effects to produce a more accurate ΔV budget.



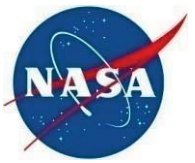


Acknowledgements

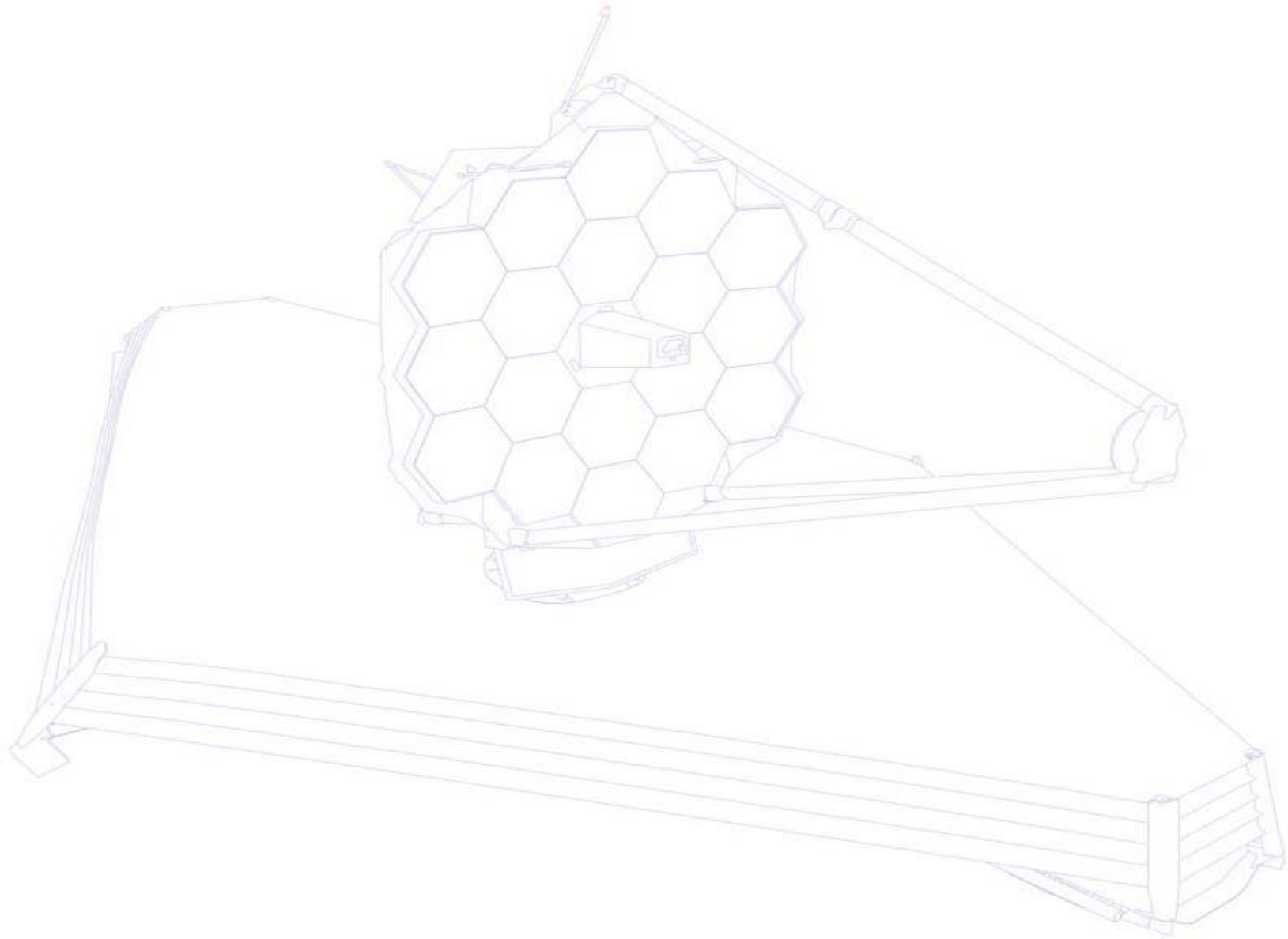


1. a.i. solutions, Inc.
2. NASA Goddard Code 595: Navigation and Mission Design Branch
 - Conrad Schiff
 - Mark Beckman
 - Leigh Forbes

JWST Presentation Topic for the ISSFD Conference	Presenter (Affiliation)	Preliminary Session and Location
Stationkeeping Monte Carlo Simulation for the James Webb Space Telescope	Donald Dichmann (NASA GSFC)	Session 13 Thursday May 8 th , 2014 10:30 - 10:50
James Webb Space Telescope Initial Mid-Course Correction Monte Carlo Implementation using Task Parallelism	Jeremy Petersen (a.i. solutions, Inc.)	Session 13 Thursday May 8 th , 2014 10:50 - 11:10
James Webb Space Telescope Orbit Determination Analysis	Sungpil Yoon (a.i. solutions, Inc.)	Session 18 Friday May 9 th , 2014 14:10 - 14:30

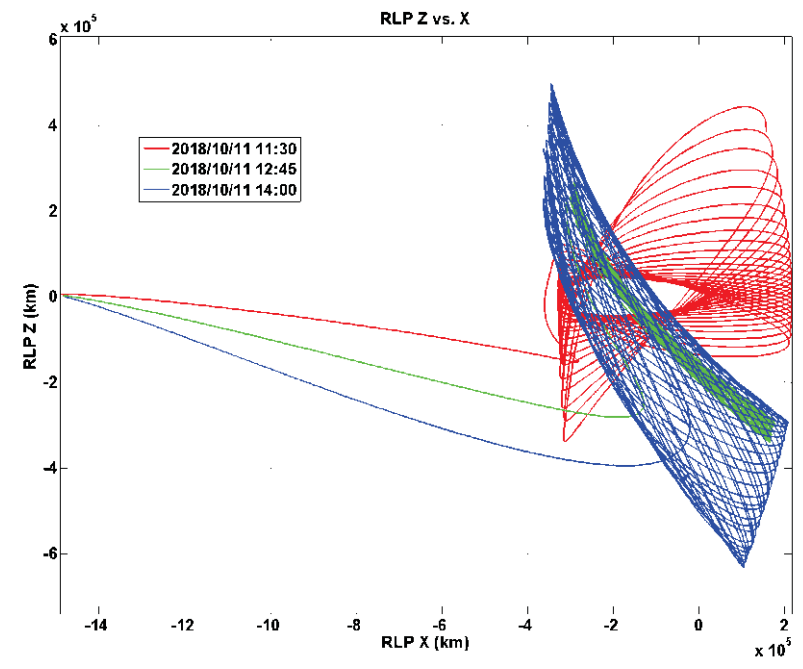
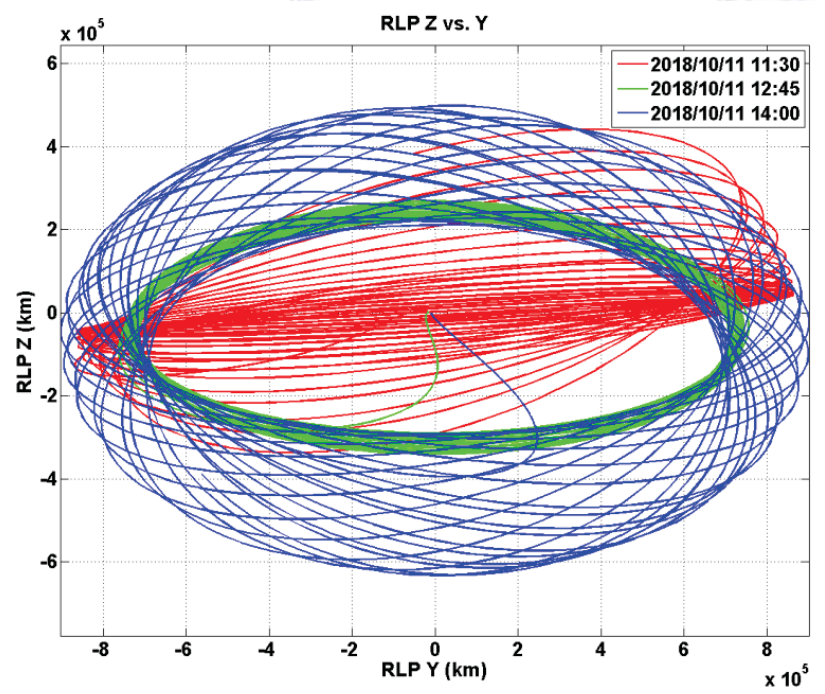
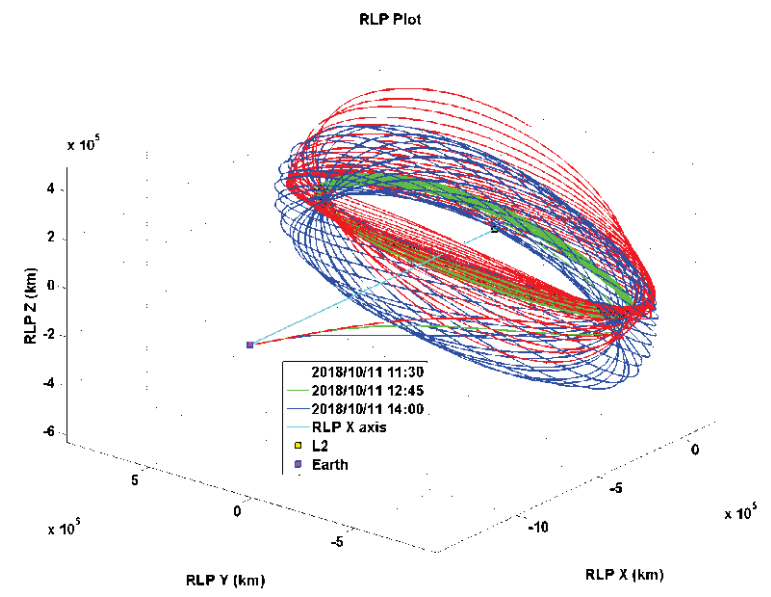
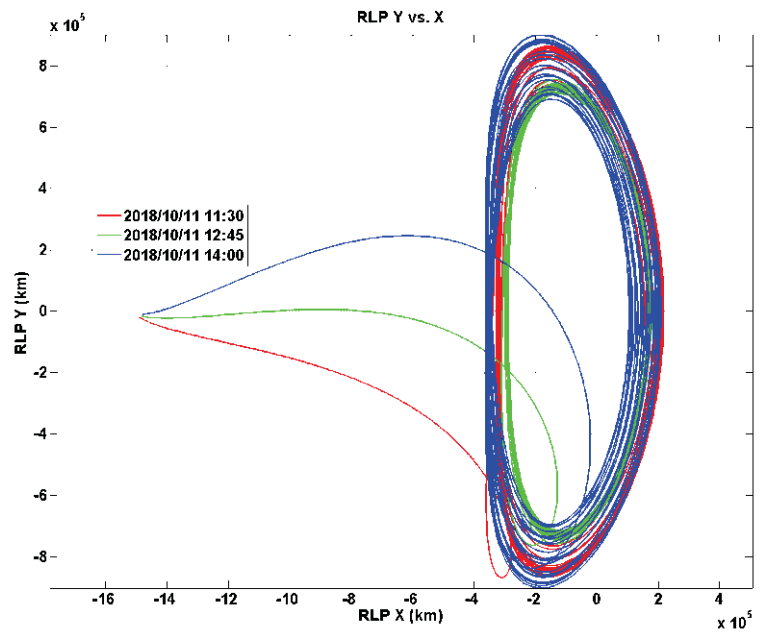


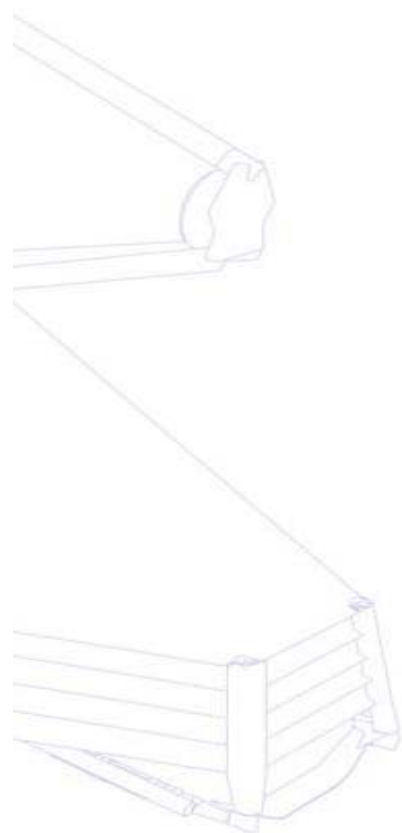
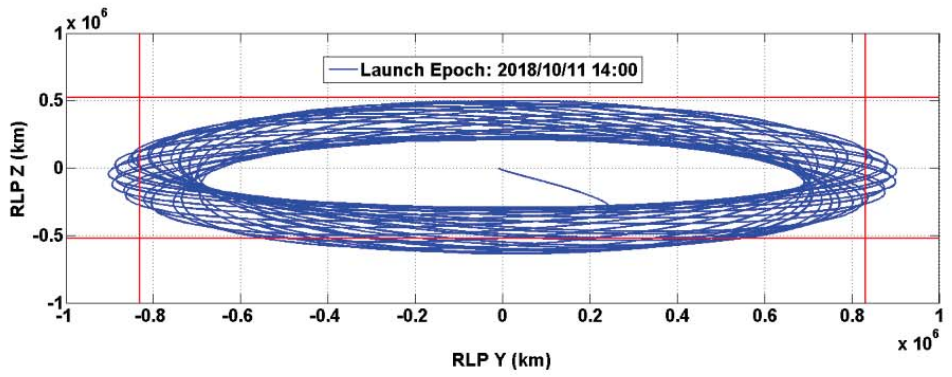
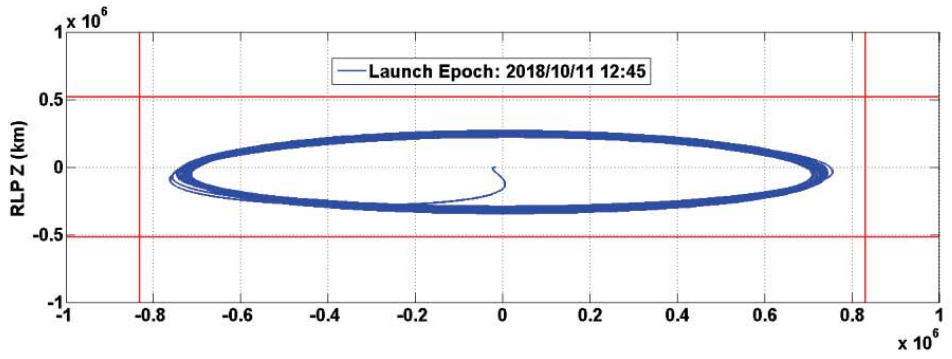
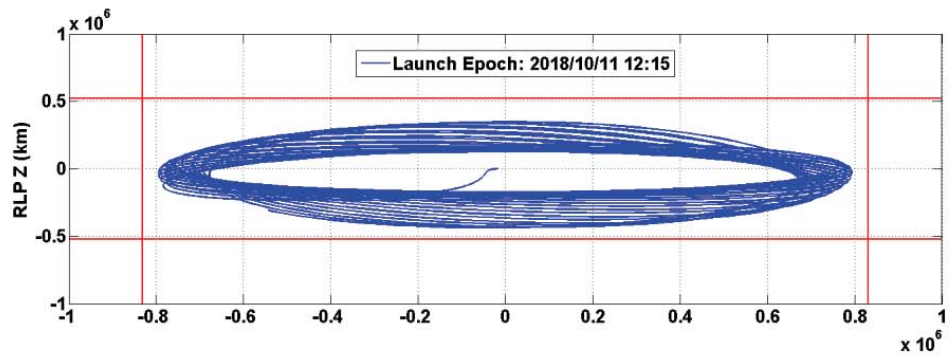
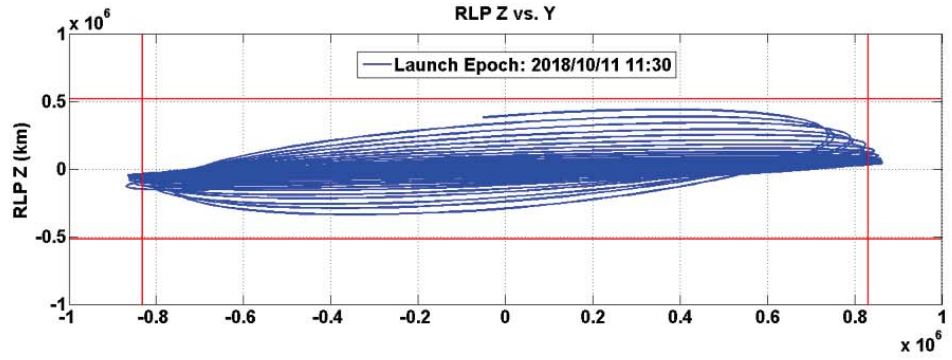
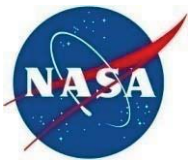
Backup



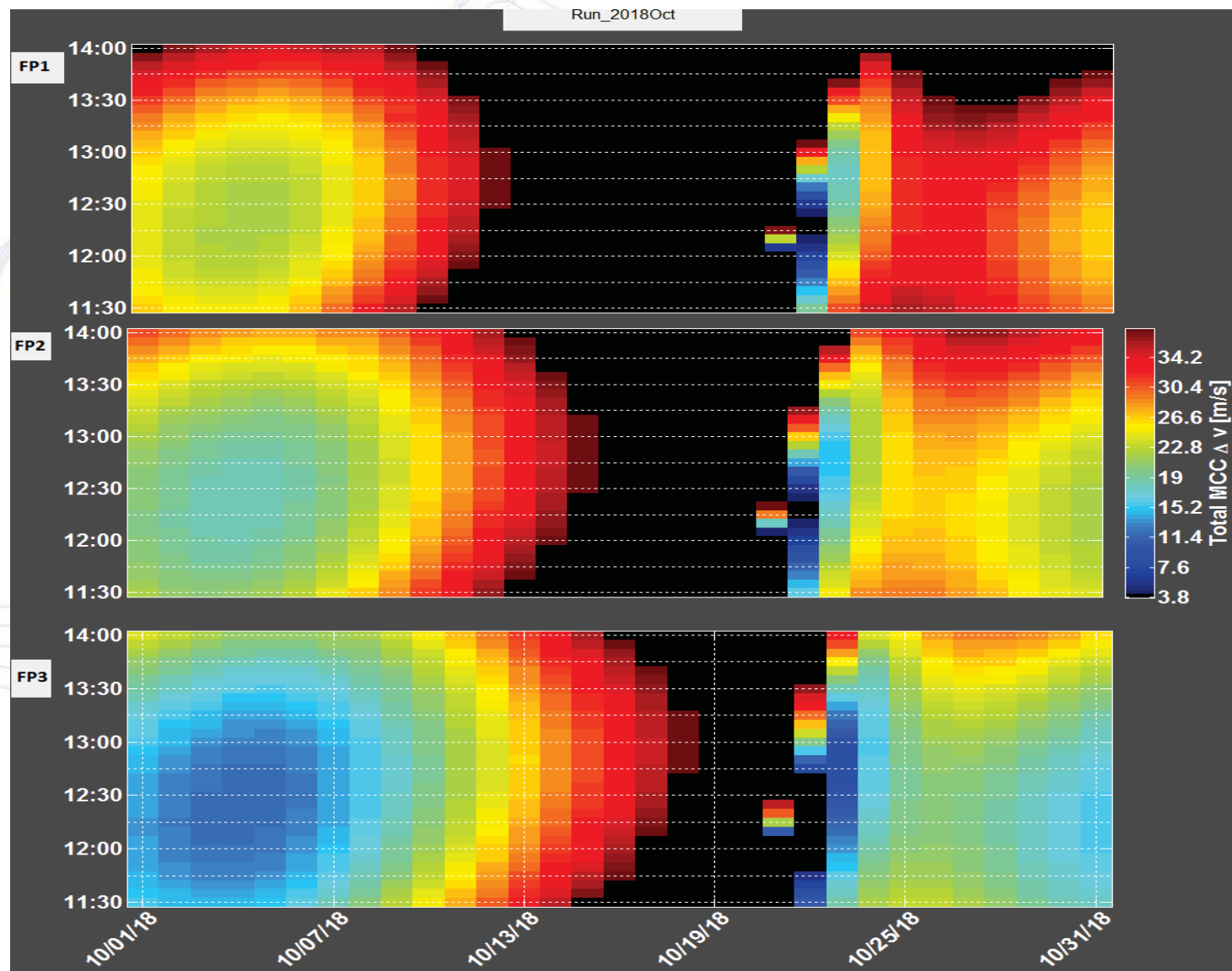


Backup



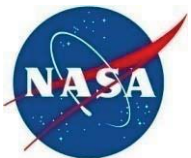


Enforced ΔV Constraint Only



The MCC Total Δv upper limit constraint holds back launch epochs between the first lunar quarter to the full moon.

The heat plot is rescaled to demonstrate the range of MCC total Δv cost.



Fully Constrained Launch Window October 2018



Enforced All Constraints

Only two days within October 2018 do not provide any launch window.

