James Webb Space Telescope
Launch Window Trade Analysis

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Agenda

• 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
Introduction

- 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 1\(^{st}\) 2018 – Nov 30\(^{th}\) 2018
  - This presentation studies the launch window in October 2018 from 11:30 – 14:00 UTC
- 10.5-year science mission goal

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

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
**Launch Vehicle**

- 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

<table>
<thead>
<tr>
<th>Designation</th>
<th>Apogee Altitude provided</th>
<th>C3 Energy Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Program 1(FP1)</td>
<td>1.02 * 10^6 km</td>
<td>-0.7665 km^2 / s^2</td>
</tr>
<tr>
<td>Flight Program 2(FP2)</td>
<td>1.06 * 10^6 km</td>
<td>-0.7381 km^2 / s^2</td>
</tr>
<tr>
<td>Flight Program 3 (FP3)</td>
<td>1.10 * 10^6 km</td>
<td>-0.7117 km^2 / s^2</td>
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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

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

![Diagram showing the relationship between the Earth, Moon, Sun, and an orbit around a libration point (RLP)].

- **RLP Y** (+/- 832,000 km)
- **RLP Z** (+/- 520,000 km)
- **RLP X Dimension**
- **1.5 x 10⁶ km**
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
Enforced LPO Orbit Size Constraint Only

The LPO Size Constraint removes launch opportunities that are early and late in each launch day.
The Earth/Moon Eclipse Constraint removes launch opportunities that are early launch times in early October 2018.
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.
Only two days within October 2018 do not provide any launch window between all 3 flight programs.
Conclusions / Future Work

- 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.
   - Conrad Schiff
   - Mark Beckman
   - Leigh Forbes

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

Start Analysis

Pavo Software

Run the JWST Orbit Mission Design

Calculate LW Metrics from the Orbit Design Output

Start Sub Process

Software Process

Software Process

Software Process

Software Process

... Collect All the Data and Generate Metrics

End Sub Process

Filter Out Data for Available Launch Window

End Analysis