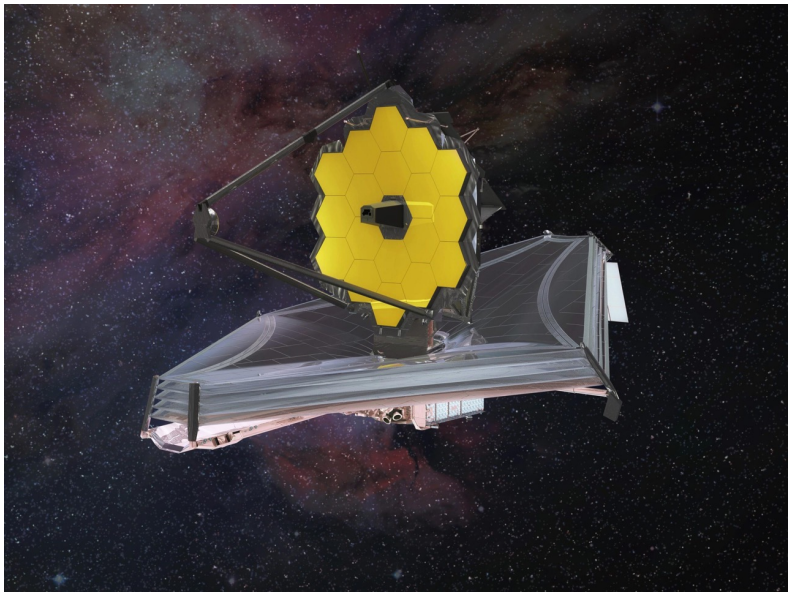


Flight Dynamics Planning and Operations Support for the JWST Mission

AAS 22-611

Karen Richon (NASA GSFC/595)

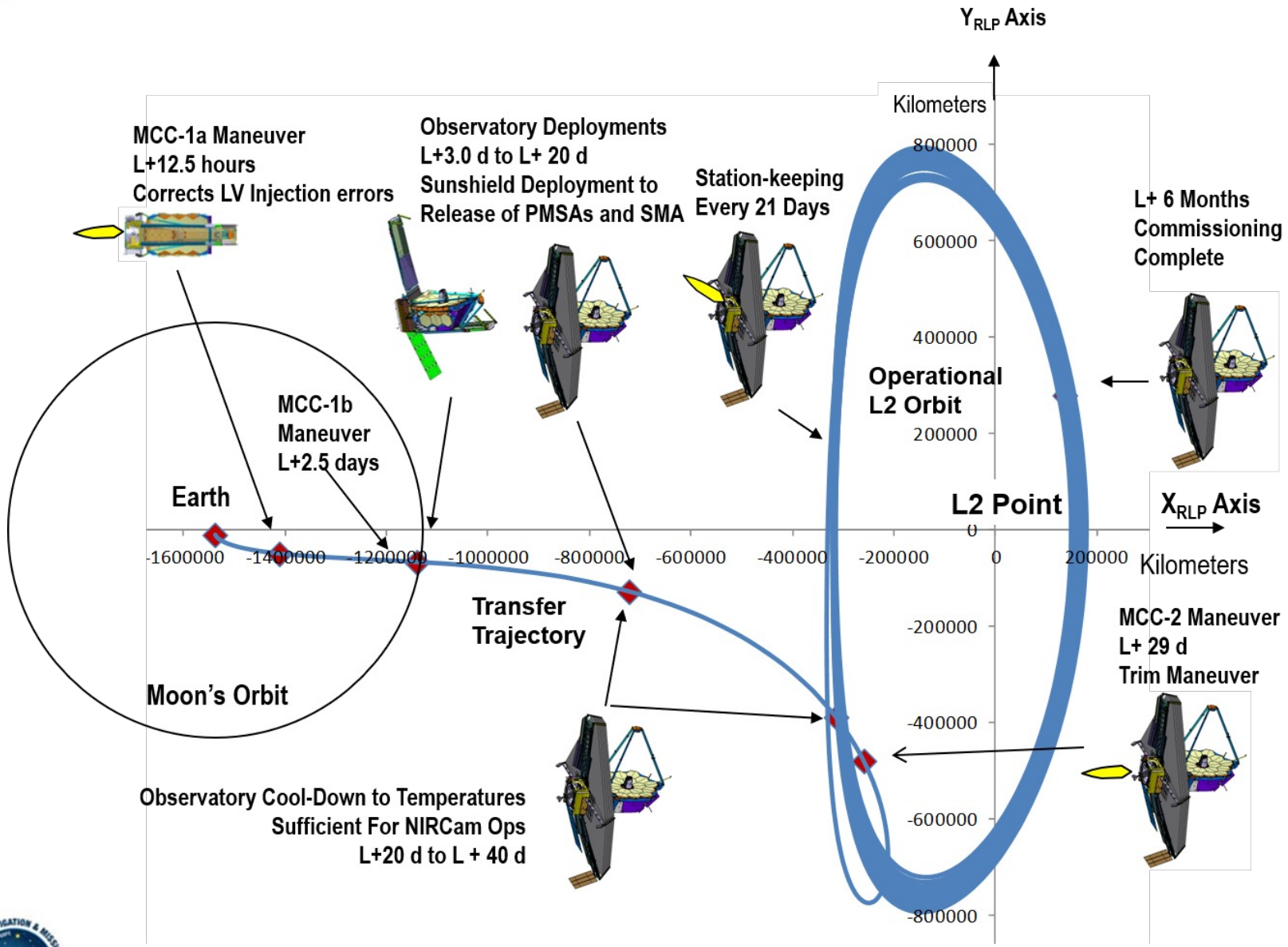
Co-authors: Jeremy Petersen & Ann Nicholson (NASA GSFC/595-ai solutions)

August 9, 2022

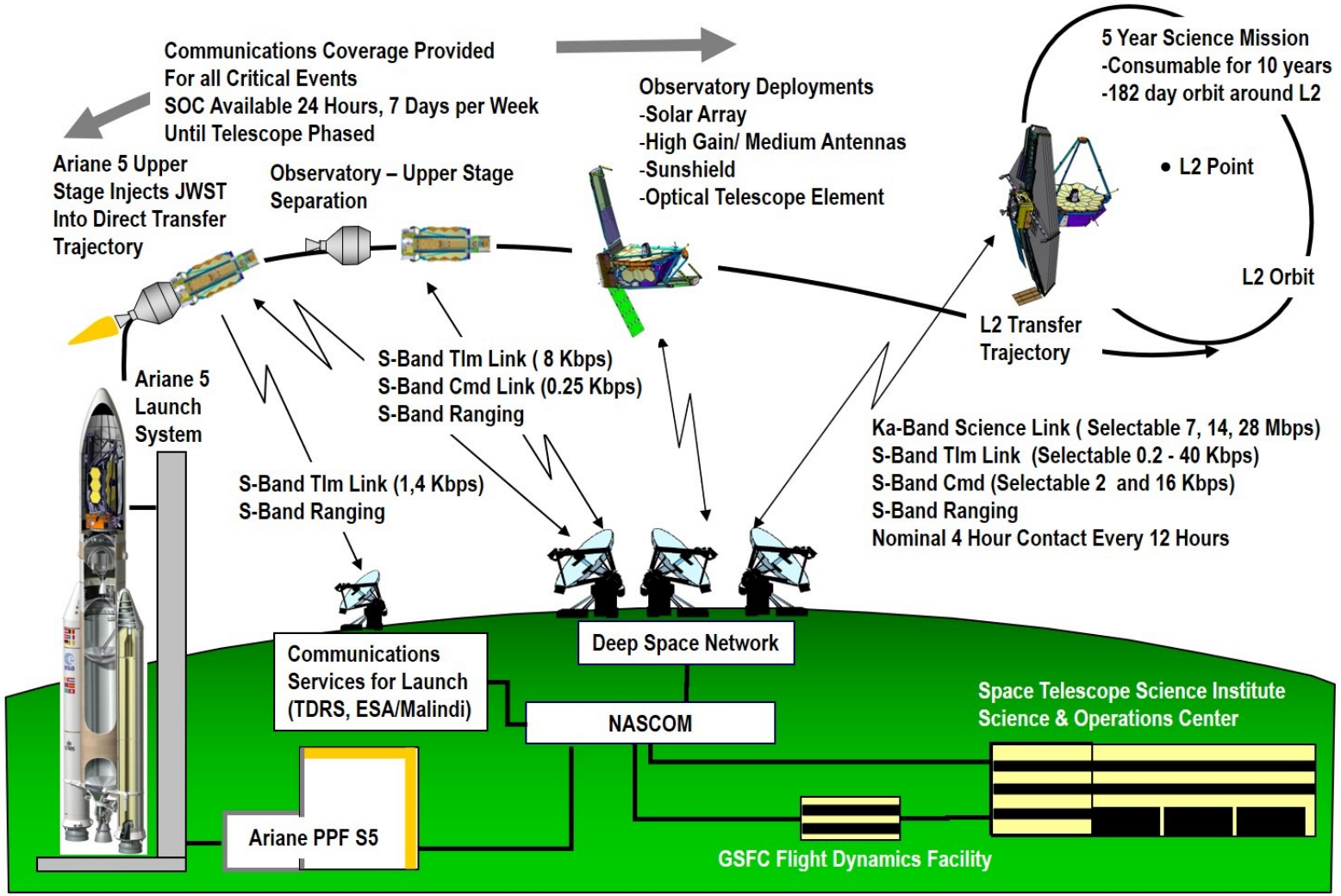
Agenda

- Overview of JWST Mission
  - Trajectory Design
  - Communications network support
- FDF Facilities and Staffing
- Planning and Prelaunch ‘tall poles’
  - Launch window for Fall 2021
  - First trajectory maneuver at L+12.5h
- On-Orbit Results
  - Launch Vehicle Accuracy
  - Mid-Course Corrections
  - Momentum Unloads
  - Stationkeeping Maneuvers
- Closing Thoughts

Planned Timeline for Transfer Trajectory

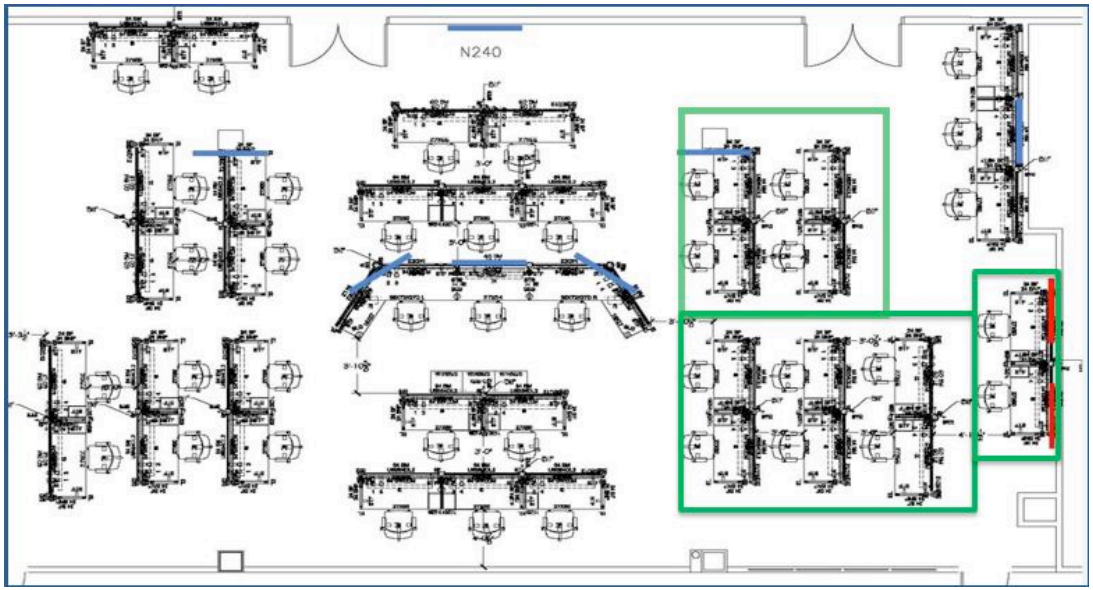


JWST Launch and Early Orbit Communications



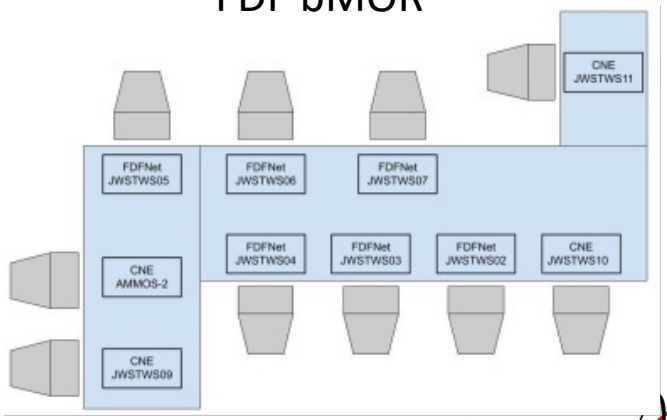
Flight Dynamics Operations Facilities

- JWST Mission Operations and Flight Operations is at Space Telescope Science Institute in Baltimore, Md.
- Flight Dynamics Facility (FDF) in Greenbelt, Md.
  - NASA Goddard Building 28
  - Flight Dynamics support from FDF Mission Operations Room (MOR)
  - Badge access only, FDF stringent IT security
  - UPS backups, Generator, and two separate power lines from power company
- Backup FDF MOR (bMOR) in NASA Goddard Building 3



FDF MOR

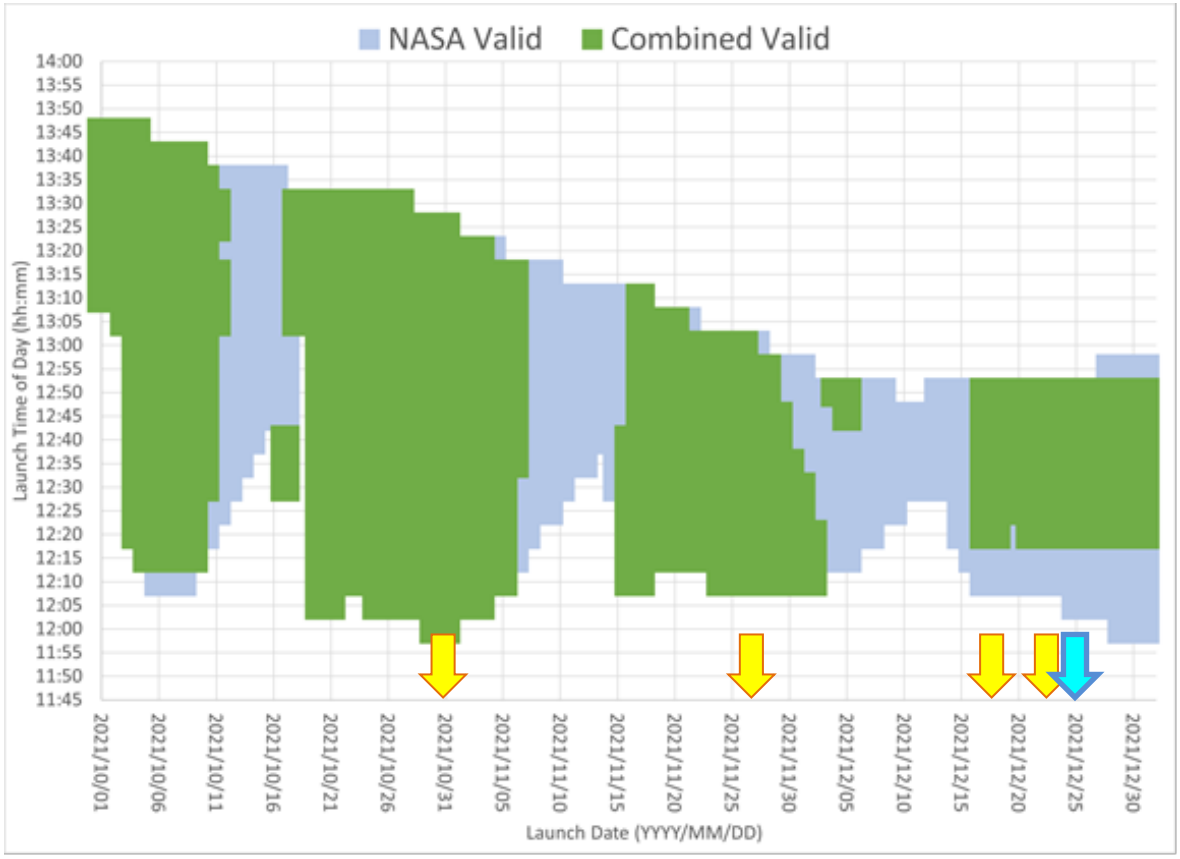
FDF bMOR



Flight Dynamics Staffing

- 24-hour support from L-6h to L+72h
  - Two 12.5-hour shifts (30 min handover)
  - Four MPs (nominal and contingency support)
  - Four ODs (Batch Least Squares, parallel Sequential Filter)
  - Shift Lead and Liaison to Flight Operations Team at STScI
- Additional launch-shift only support
  - Two TDRSS acquisition data personnel
  - One FDF Systems Administrator
  - Two Software Engineers
  - Two Electricians for Generator
  - FD Experts (to assist with launch-related contingencies)
- Daily support through L+30 days
- Weekday support through L+180 days
- 2-3 weekdays support or as needed thereafter

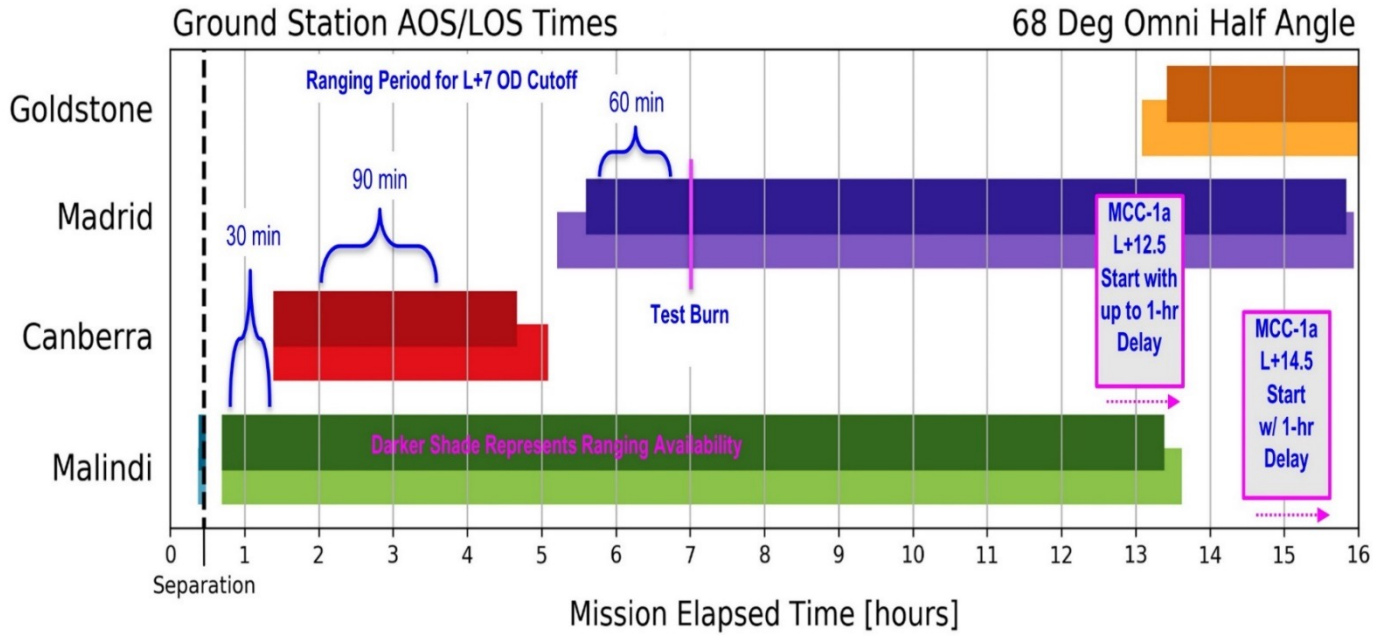
JWST Launch Window



- Combined Valid: meets all NASA, ESA & Ariane Group constraints
- Primary Launch dates for which FD generated & delivered products
  - October 31, November 26, December 18, December 22

JWST Launched December 25th 12:20 UTC

An Early Orbit Challenge: MCC-1a at L+12.5 hr



- Much earlier than most SEM libration point missions
  - Orbit Determination (OD) tracking data arc to end at L+7h
  - OD solution ready for Maneuver Planners (MPs) by L+7.5h
  - MPs generate & deliver Final MCC-1a Plans and Products to FOT by L+8.5h
- Needed three tracking sites separated geographically to achieve OD solution with short arc
  - 3rd DSN station (Goldstone) contact not possible in 1st 7 hours
  - Drove requirement for Malindi tracking measurements to supplement DSN
- FDF had to test and verify its use of Malindi tracking data with realtime tracking of on-orbit spacecraft
  - Pandemic shutdown delayed completion of Themis and Malindi testing for a year+

Ariane 5 and MCC Performance

- **Ariane 5/ESC-A+ delivered JWST on target within 0.08 sigma of predicted LV dispersions**
- No extra JWST dV was needed to correct dispersions in MCC maneuvers
- MCC maneuvers were accurate to within 0.8% of predicted
- MCC-2 was performed a day later than planned (on L+30 days, January 24, 2022) without noticeable dV penalty
- **Unused MCC propellant could provide 46.2 m/s additional dV**
- **Mission lifetime could be 20+ years**

MCC Costs for Launch on December 25, 2021, 12:20 UTC (m/s)				
Source	**MCC-1a**	**MCC-1b**	**MCC-2**	**MCC Total**
Prelaunch	20.468	2.518	1.267	24.253
Maneuver Plans	20.202	2.780	1.468	24.450
DVALOS	19.904	2.752	1.461	24.117
Orbit Determination	20.046	2.763	1.457	24.266

Simplified Δv budget for JWST.

Maneuver Type	**Delta-V Allotment (m/s)**	**Notes**
MCC nominal	57.9	Accounts for up to 3-sigma LV dispersions
MCC contingency allotment	12.6	Extra Δv for delay of MCC-1a execution
Station-keeping for 10.5 years	26.0	Includes 2.4 m/s of contingency
End of life disposal	0.7	
Total Δv allocated pre-launch	97.2	
Full propellant load (possible Δv)	**109.8**	**Up to 12.6 m/s additional Δv available (109.8 – 97.2)**

Momentum Unloads through August 1, 2022

Name	Date (UTC)	Duration (sec)	Delta-V (cm/s)
MU-001	2021-12-28 12:29	163.840	0.057
MU-002	2021-12-28 21:42	622.595	0.060
MU-003	2021-12-29 10:28	262.144	0.090
MU-005	2021-12-31 23:45	360.448	0.253
MU-006	2022-01-03 14:33	557.056	0.383
MU-007	2022-01-04 10:17	229.376	0.160
MU-008	2022-01-19 18:12	393.216	0.508

- 8 Momentum Unloads (MUs) between MCC1a and MCC2
  - Small impact on trajectory
- MUs since then have been fewer, less impact
- MUs are much less often than expected

Station-Keeping Maneuvers through August 1, 2022

Name	Date (UTC)	Direction	Duration (sec)	Delta-V Plan (cm/s)	Delta-V Achieved (cm/s)	Performance (%)
SK-001	2022-02-16 21:55	Anti-Sunward	21.448	10.32	10.49	1.6
SK-003	2022-03-30 14:54	Anti-Sunward	17.352	8.40	8.78	4.5
SK-005	2022-05-03 14:49	Anti-Sunward	13.256	6.46	8.70	34.7
SK-006	2022-06-01 15:05	Sunward	7.112	3.17	3.18	1.0
SK-008	2022-07-13 14:42	Anti-Sunward	20.224	9.91	8.96	-7.5

- Station-keeping maneuvers have occurred less frequently than planned prelaunch
- SK-005 end of maneuver tripped a fault, so it went to Safe Haven attitude using attitude thrusters
- Science instrument commissioning was higher priority than SKs in 1st 6 months
- Science operations only started a month ago, not enough time to evaluate whether SK cadence could be increased to more than 21 days
- Still characterizing the performance

Closing Thoughts

- NASA GSFC flight dynamics support enabled success-oriented early mission timeline so that MCC1a could occur at L+12.5h
- Extensive work with spacecraft manufacturer to model propulsion system paid off – MCC maneuvers' performances were 1% of predicted
- Contingency procedures were extensive, but not needed for off nominal separation or MCC issues
- FDF Certification to use Malindi tracking was completed in spite of COVID limitations on personnel and operations facilities
- Malindi tracking data enabled orbit determination for MCC-1a planning
  Ariane 5 delivered JWST to a near-perfect separation state
- MUs are much less often than expected
- Too early to say if we will change SK cycle, and need to characterize performance
- JWST lifetime in terms of propellant is expected to be at least 20 years, twice the goal, four times the required lifetime

Acknowledgements

Ty Burney
Michael Goff
Kennedy Haught
Arvind Kaushik
Jon Landis
James Logan
John Lorah
Steven Magnusen
Ishaan Patel
Annie Ping
Taabish Rashied
Megan Renshaw
Jose Rosales
Michael Schmidt
Jeff Small
Ben Stringer
Eric Stoker-Spirt
Jennifer Yantorno
Charles Yu
Wayne Yu
Matt Zuckerman


Questions?





