

James Webb Space Telescope Station Keeping Analysis

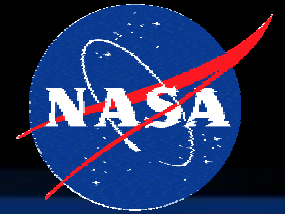
Mark Beckman & Anne Delion

Flight Dynamics Analysis Branch GSFC • May 2003

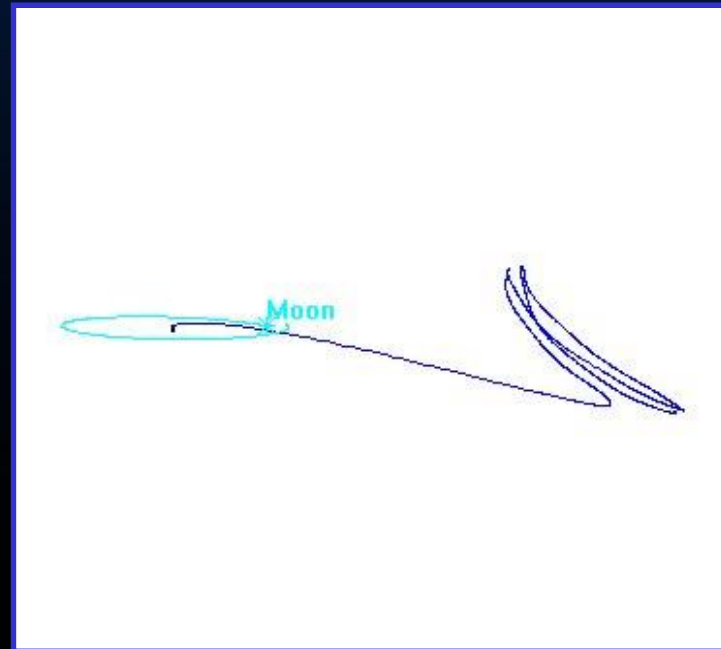
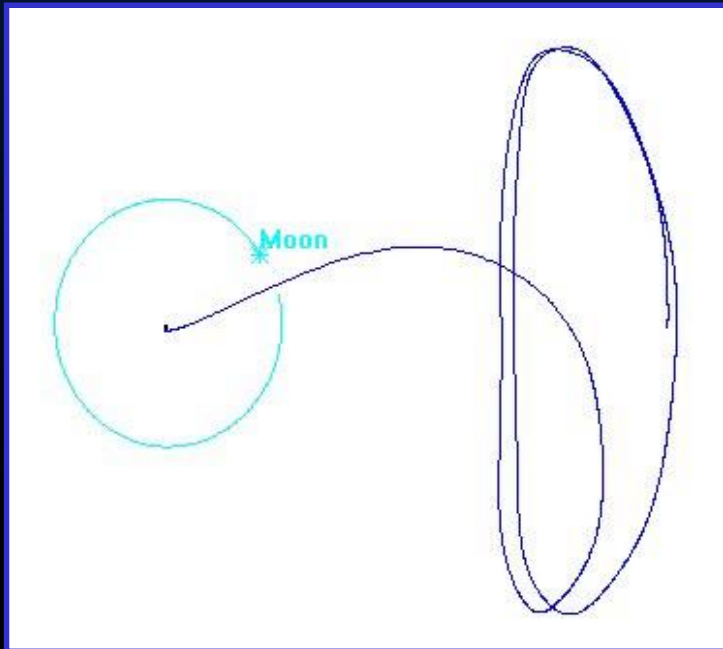
www.stk.com



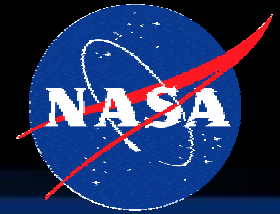
James Webb Space Telescope



- JWST is planned to launch in 2011
- Large Sun/Earth L_2 halo orbit



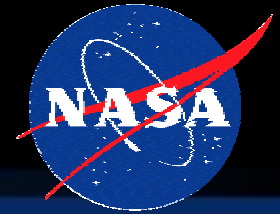
Libration Point Orbits



- Sun/Earth halo orbits have periods of approximately six months
- Large halo orbits eliminate possibility of shadows
- Collinear libration points are unstable
- Initial conditions can be chosen to obtain a periodic orbit
- Errors cause deviation from reference trajectory
 - Orbit determination
 - Maneuver execution
 - Force modeling
 - Spacecraft perturbations



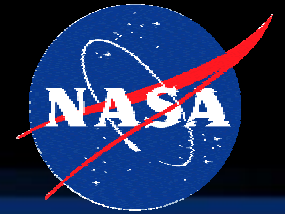
JWST Error Sources



- 3 cm/sec orbit determination accuracy
- 5% maneuver execution accuracy
- Unpredictable large solar shield orientation gives up to 27 m² cross-sectional area uncertainty for solar radiation pressure force calculations
- Momentum unloads of up to 8 mm/sec, due to using unbalanced thrusters, as often as every 4 days



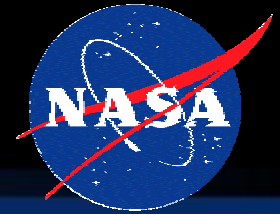
STK Tools



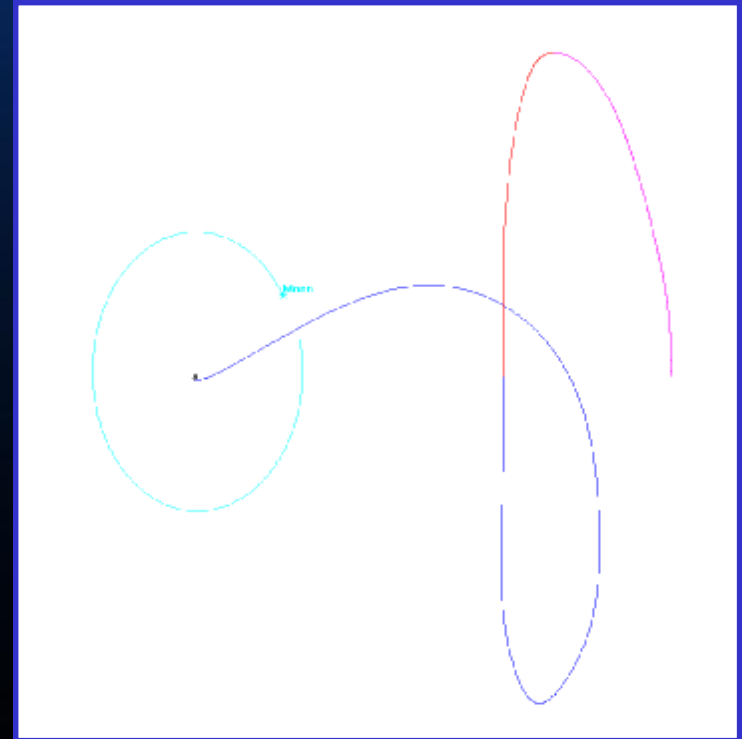
- ***Astrogator*** to model and target the L_2 halo orbit
- ***Connect*** to automate targeting and build ***Astrogator*** Segments
- ***Matlab Interface*** to provide logic control for advanced analysis and Monte Carlo simulations



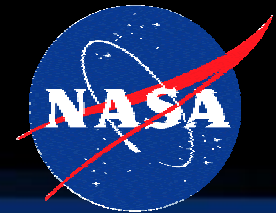
Halo Orbit Balancing



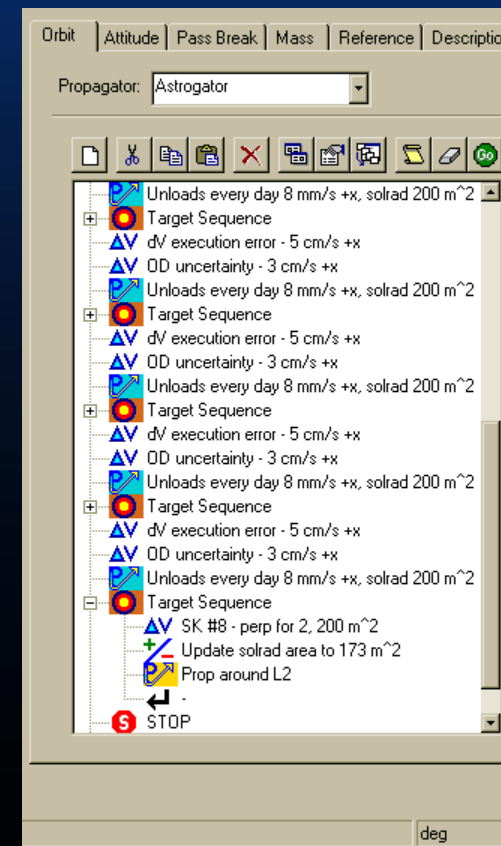
- Rotating Libration Point coordinate system
 - X is along Sun/Earth line towards Earth
 - Z is perpendicular to Ecliptic
- Periodic halo orbits are symmetric about the XZ -plane
- Halos orbits are considered balanced when future crossings of the XZ -plane are perpendicular
- Simplest to target $X\text{-dot}$ equal to zero (ignore $Z\text{-dot}$)



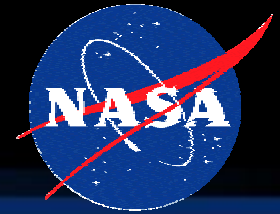
Mission Control Sequence



- Starting with a balanced L_2 halo orbit
- Introduce errors such as OD, dV execution and momentum unloads
- Change SRP to represent worst case
- Propagate errors to location of next station keeping maneuver
- Target station keeping maneuver such that orbit is balanced



Momentum Unload Modeling



- Sub-sequence required to accurately model momentum unloads
- Propagation segment consisting of two Stopping Conditions
- First condition stops every 4 days and performs Impulsive Maneuver (unload)
- Second condition stops at the next station keeping maneuver

Trajectory Propagation

Propagator: Libr Pt

Stopping Conditions:

Name	User Comment	Description
Duration	Momentum unload every 4 days	Stop after a sp
Duration1	Prop to next SK maneuver	Stop after a sp

Trip: 86400.00000000 sec

Tolerance: 0.00000001 sec

Sequence: JWST momentum unlo

User Calc. Object:

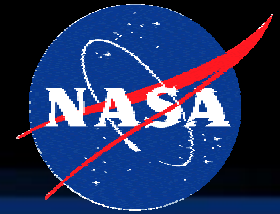
User Comment: Momentum unload every 4 days

Initial: 1 Nov 2005 08:04:23.53

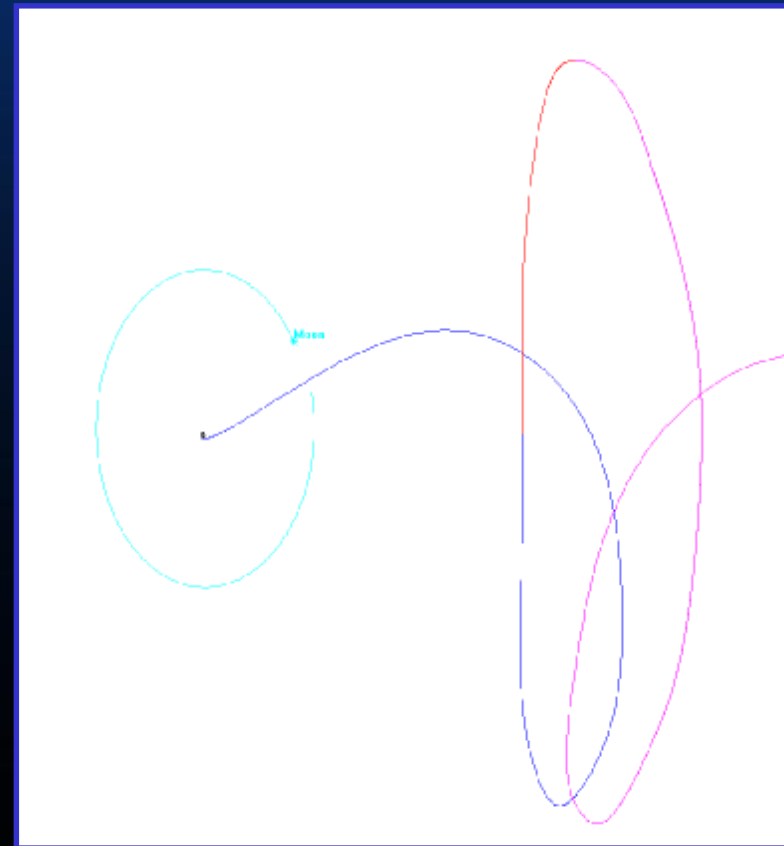
Final: 16 Dec 2005 08:04:23.53

UTCG km kg sec

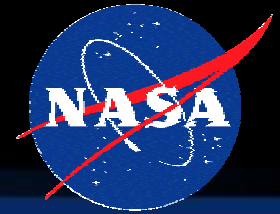
Repeat Targeting



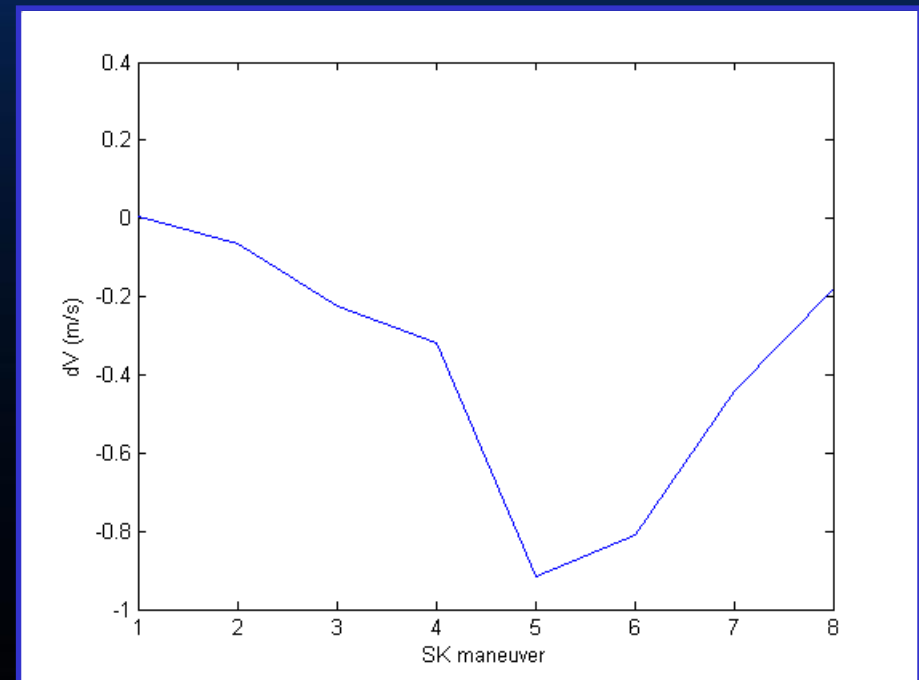
- Well balanced halo orbits target to 2nd or 3rd future XZ-plane crossing
- In the presence of trajectory perturbations, a 2nd or 3rd crossing may not exist because the trajectory departs the region
- Need to first target 1st future crossing to get accurate enough initial guess



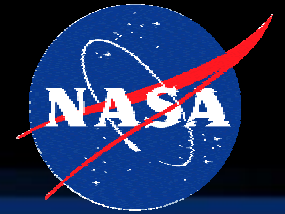
Station Keeping Results



- SK maneuver magnitude varies greatly depending on location in orbit
- Possible reduction in dV budget by choosing targets that result in less momentum buildup during sensitive periods



Matlab Automation



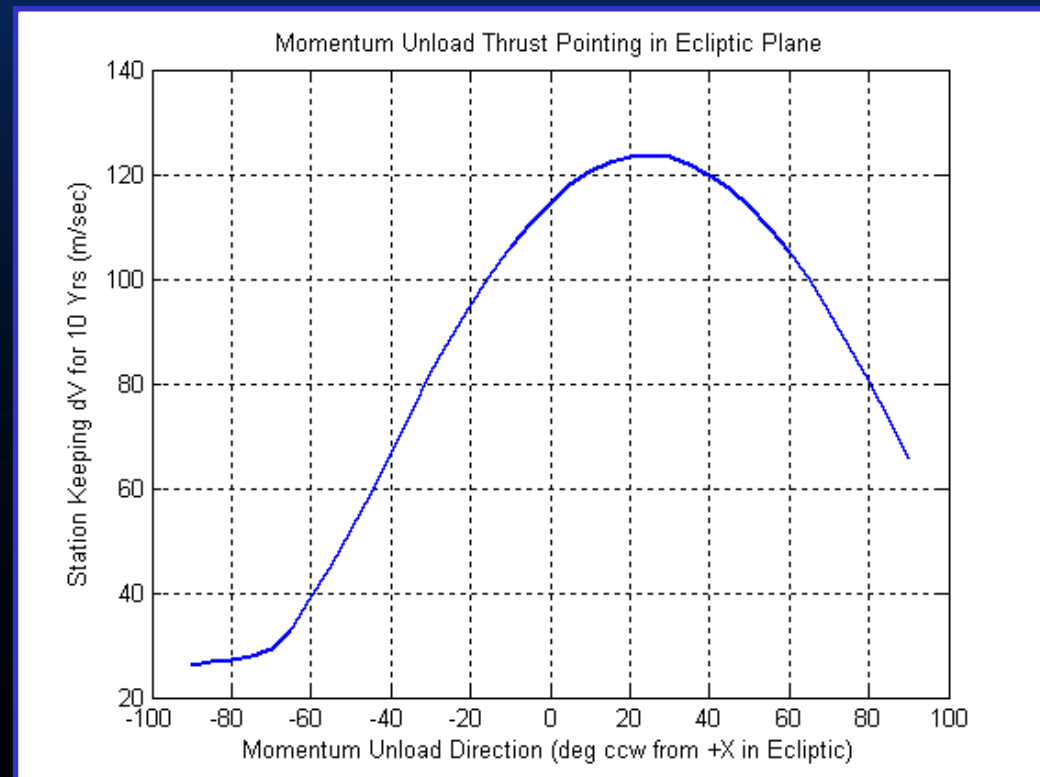
- Allows user defined or random error sources including magnitude, direction, and frequency
- Allows user defined location or spacing of station keeping maneuvers
- Allows parametric studies of different combinations of error sources
- Ultimately may allow optimization of control strategy



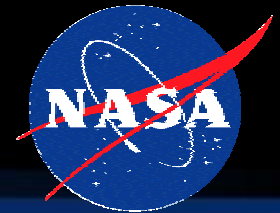
Sensitivity Results



- Indicates dV budget greatly depends on direction of perturbations in the Ecliptic plane
- Ability to reorient spacecraft prior to momentum unloads would greatly reduce dV budget



STK Capabilities



- Use of **STK** and **Astrogator** (instead of just **Matlab**) allows high-fidelity modeling, high quality graphics, and a large range of output options and takes advantage of the **Astrogator Segments** to facilitate quick trajectory design
- Sub-sequences and Constraints allow fairly complex MCS
- **Astrogator Browser** allows creation of Calc Objects for unique targeting or output requirements
- **Connect** support of **Astrogator** commands makes complex and repetitive analysis possible
 - Segment naming needs improvement
 - Ability to apply/clear targeter corrections needed

