STATIONKEEPING MONTE CARLO SIMULATION FOR THE JAMES WEBB SPACE TELESCOPE

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ABSTRACT

The James Webb Space Telescope (JWST) is a scientific successor of the Hubble Space Telescope and the Spitzer Space Telescope, designed to study and answer fundamental astrophysical questions ranging from the formation of the Universe to the origin of planetary systems and the origins of life. The project is working toward a 2018 launch.

JWST will fly in a Libration Point Orbit around the Sun-Earth/Moon (SEM) L2 point, with a planned mission lifetime of 11 years. Stationkeeping (SK) maneuvers will be performed every 21 days to maintain orbit around the unstable SEM L2 point. SK maneuvers are needed to correct for orbit determination errors, previous maneuver execution errors, momentum unloads (MUs), uncertainty in Solar Radiation Pressure (SRP), and other force modeling errors. This paper discusses our approach to SK maneuver planning, the modeling of perturbations, the structure of a Monte Carlo simulation, and the simulation results to determine a conservative SK delta-V budget.

The planning of SK maneuvers for JWST is made particularly challenging by two factors: JWST has a large (about 165 m^2), complex, multi-layer sunshade, and JWST will be repointed regularly producing significant changes in SRP. It was therefore important to develop an accurate, attitude-dependent model of SRP. For this we employed NASA Goddard's Solar Pressure and Drag (SPAD) tool, which uses ray tracing to accurately compute SRP force and torque as a function of attitude based on a spacecraft model including geometric and reflectivity parameters. The resulting SRP model is also used in JWST's orbit determination analysis, described in a companion paper.

As an additional challenge, the JWST observation schedule in the next 21-day period may not be known at the time of SK maneuver planning. Thus there will be significant variation in SRP between SK maneuvers, and the future variation in SRP is unknown. To determine an adequate SK delta-V budget, we have enhanced an earlier SK simulation to create a Monte Carlo simulation that includes random draws for orbit determination errors, maneuver execution errors and spacecraft attitude. To obtain a conservative SK budget, we used a uniform distribution of attitude within the constraints of spacecraft pointing to prevent the telescope from being exposed to stray light. In a separate Monte Carlo simulation, we modeled attitude history using a collection of 197 representative observation schedules developed by the Space Telescope

Science Institute (STScI) for JWST. MU schedules provided by STScI were also used in the simulation. Each SK maneuver is planned to optimize delta-V magnitude, subject to constraints on spacecraft pointing, so that JWST remains in a libration point orbit. We report the results of the Monte Carlo simulations for the SK delta-V budget. We also discuss possible approaches to improve SRP predictions during flight operations, to reduce uncertainty in SK planning and perhaps extend mission lifetime.