

James Webb Space Telescope Orbit Determination Analysis

Sungpil Yoon⁽¹⁾, Jose Rosales⁽²⁾, and Karen Richon⁽³⁾

^(1,2)*a.i. solutions, Inc., 10001 Derekwood Lane, Lanham, MD 20706, 301-306-1756,
sungpil.yoon@ai-solutions.com, jose.rosales@ai-solutions.com*

⁽³⁾*Code 595, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, 301-286-8845,
karen.v.richon@nasa.gov*

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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. JWST is being developed by the National Aeronautics and Space Administration, the European Space Agency and the Canadian Space Agency. The project is working toward a 2018 launch.

JWST will be placed in an orbit about Sun-Earth L2 libration point. The Sun-Earth L2 libration point is located about 1.5 million km from Earth (four times the distance to the Moon) on the opposite side of the Sun from the Earth. The JWST orbit's maximum distance from the Earth will be 1.8 million km.

JWST's velocity determination requirement during the nominal science phase is largely driven by its contribution to station keeping maneuver planning. A large orbit determination (OD) error at the time of station keeping maneuver design will result in a larger actual station keeping maneuver error, which will lead to more fuel consumption for station keeping and an overall shorter mission lifetime. The current OD requirement is 50 km ($3\text{-}\sigma$) for position and 2 cm/sec ($3\text{-}\sigma$) for velocity.

JWST will have a large sunshield with a maximum effective solar radiation pressure (SRP) area of $\sim 165\text{ m}^2$. The purpose of the sunshield is to protect the JWST optical system from infrared sources, including the Sun, Earth, and Moon and spacecraft bus electronics. The unusually large SRP force acting on the huge sunshield poses the major challenge to accurate JWST OD during the nominal science phase. Other challenges are frequent attitude reorientations to align the JWST telescope with its targets and frequent maneuvers to unload accumulated momentum in the reaction wheels.

Updates to JWST OD performance have not been published since the original navigation concept paper in 2003. This paper describes the current expectation of the OD performance and methods applied for two mission phases (early orbit phase and nominal science phase).

For the early orbit phase ($\sim L+12$ hours), preliminary analysis has been done and the method and results are described in this paper. According to the current analysis, **the position knowledge error is better than 1 km RSS**. There is no OD requirement for this phase; however, the quality of the OD solutions at this stage is critical to the design and execution of the first midcourse correction maneuver, which occurs at $L+12$ hours. The following analysis assumptions were

made: (1) near-continuous range and range-rate data from three DSN ground stations (2) a Batch Least Squares method using FreeFlyer® from a.i. solutions, Inc.

For the nominal science phase, preliminary Monte Carlo analysis has been performed; the method and results are described in this paper. Results from this analysis indicate **the OD requirements for position and velocity knowledge are met**. The following assumptions were made: (1) momentum unloading maneuvers occurring every 3 days with realistically modeled directions and magnitudes (2) station keeping maneuvers every 21 days with realistically modeled directions and magnitudes (3) realistic attitude profile based on science pointing schedule (4) range and range-rate data from three DSN ground stations (5) use of an Extended Kalman Filter with the Orbit Determination ToolKit® from Analytical Graphics, Inc.

This paper will explain the benefits and reasons for using the two OD methods, and discuss future analysis.