Title:

The OPALS Plan for Operations: Use of ISS Trajectory and Attitude Models in the OPALS Pointing Strategy

Authors:

Matthew J Abrahamson, Bogdan Oaida, Baris Erkmen†
† Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA, 91109.

Abstract:

The Optical Payload for Lasercomm Science (OPALS) Flight System is currently being developed at the Jet Propulsion Laboratory (JPL) and will demonstrate a space-to-ground optical communications link on the International Space Station (ISS) in late 2013 / early 2014. The Flight System will be mounted to the nadir-facing Express Logistics Carrier-1 (ELC-1) on the ISS exterior, ensuring line of sight to the OPALS ground station, known as the Optical Communications Test Laboratory (OCTL), located at Table Mountain, California. A major technical challenge of any optical communication system is maintaining stable and accurate pointing between the optical transmitter and receiver. For a transmitter attached to the ISS platform, this requires accurate tracking of the receiver ground station as the ISS passes overhead. At the average ISS altitude of 400km and velocity of 7 km/s, a two-axis gimbal must slew with an angular velocity between 0.2°/sec and 1.2°/sec along track and ±0.2°/sec cross track to maintain lock on the ground station through a typical 2 to 3-minute pass.

The OPALS operations plan calls for bi-directional pointing between OCTL and the OPALS Flight System to establish and maintain an optical link. At OCTL, a two-axis telescope orients the optical receiver and a laser beacon toward the ISS. The laser beacon serves as the point of reference for the Flight System tracking system, while the receiver captures the optical transmission from the Flight System. On the Flight System, a two-axis gimbaled optical transceiver consisting of a co-aligned optical transmission beam and tracking camera is pointed back toward the laser beacon. The transceiver initially searches for the laser beacon, then, once the beacon is acquired by the camera, tracks it using a closed-loop control system for the remainder of the pass. Since the camera and optical transmission beam are co-aligned, the optical transmission will be pointed to the optical receiver when the laser beacon is in lock.

The execution of this pointing strategy requires the use of ISS trajectory and attitude predictions. The ground-to-flight pointing profile is defined in the OCTL Pointing File as a time-series of local topographic angles that are computed from an ISS trajectory prediction. Similarly, the flight-to-ground pointing profile is defined in the Blind Pointing File as a time-series of local payload gimbal angles, based on an ISS platform definition established by ISS trajectory and attitude predictions. The two prediction products differ in their requirements. While the OCTL Pointing File is intended to track the ISS open

loop throughout the pass, the Blind Pointing File is only intended to search for the laser beacon up until beacon acquisition and becomes inactive once the beacon is in lock. The OCTL Pointing File requirements are driven by the need to keep the ISS within a half beamwidth of the laser beacon and to need to point the receiver toward the optical transmission beam. In order to accomplish this, the OCTL Pointing File errors are required to be less than ±250 μrad. The Blind Pointing File requirements are driven by the need to detect the beacon signal in the tracking camera field of view. After budgeting for pointing errors due to ISS platform misalignments and flexing, the Blind Pointing File errors due to trajectory and attitude dispersions is required to be less than ±0.5°.

This paper will discuss the OPALS pointing strategy, focusing on incorporation of ISS trajectory and attitude models to build pointing predictions. Methods to extrapolate an ISS prediction based on past data will be discussed and will be compared to periodically published ISS predictions and Two-Line Element (TLE) predictions. The prediction performance will also be measured against GPS states available in telemetry. The performance of the pointing products will be compared to the allocated values in the OPALS pointing budget to assess compliance with requirements.

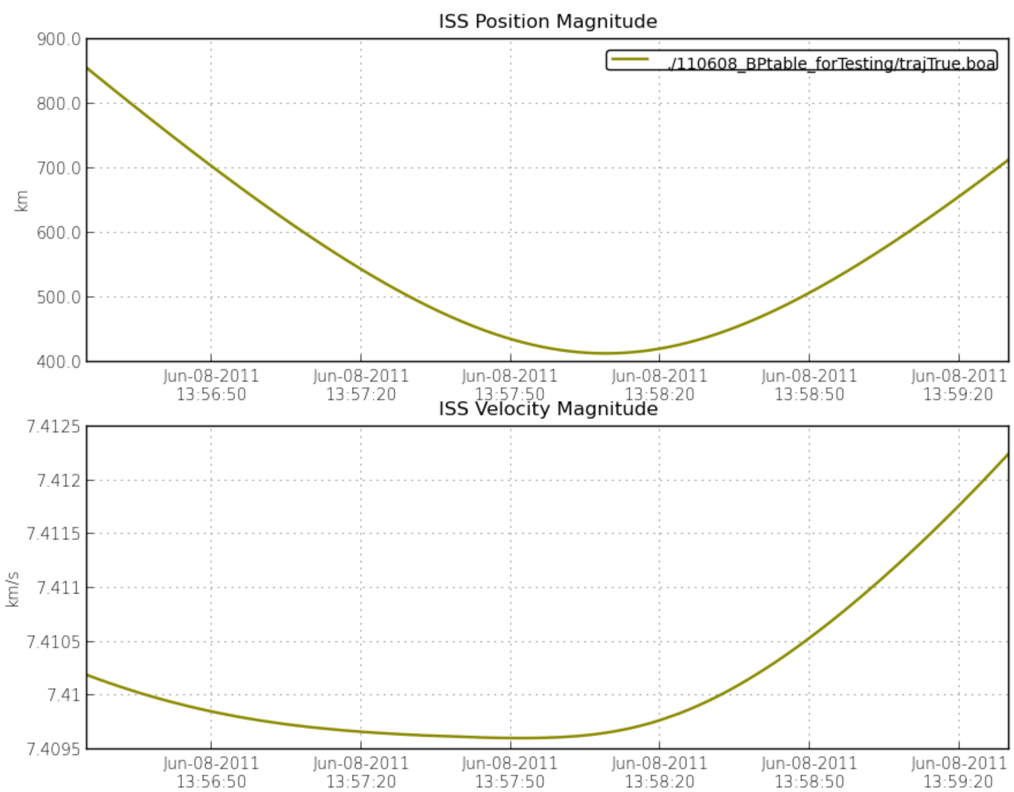

Figure 1. Altitude and Velocity of the ISS During a Typical OCTL Flyover

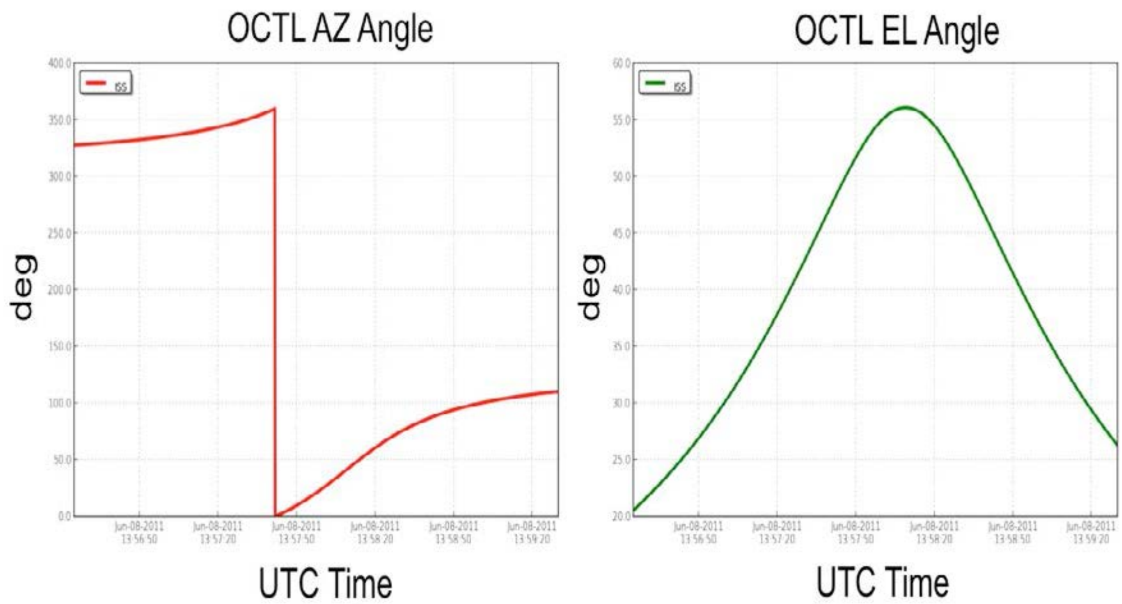

Figure 2: Angles in the OCTL Pointing File

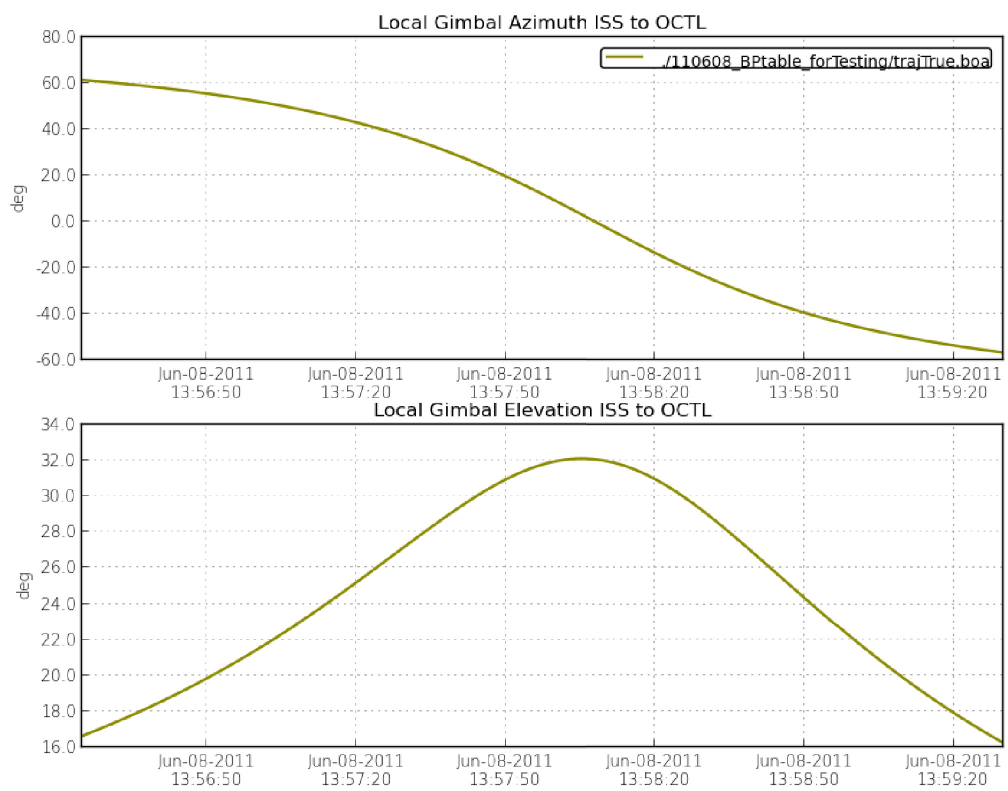

Figure 3. Angles in the Blind Pointing Table

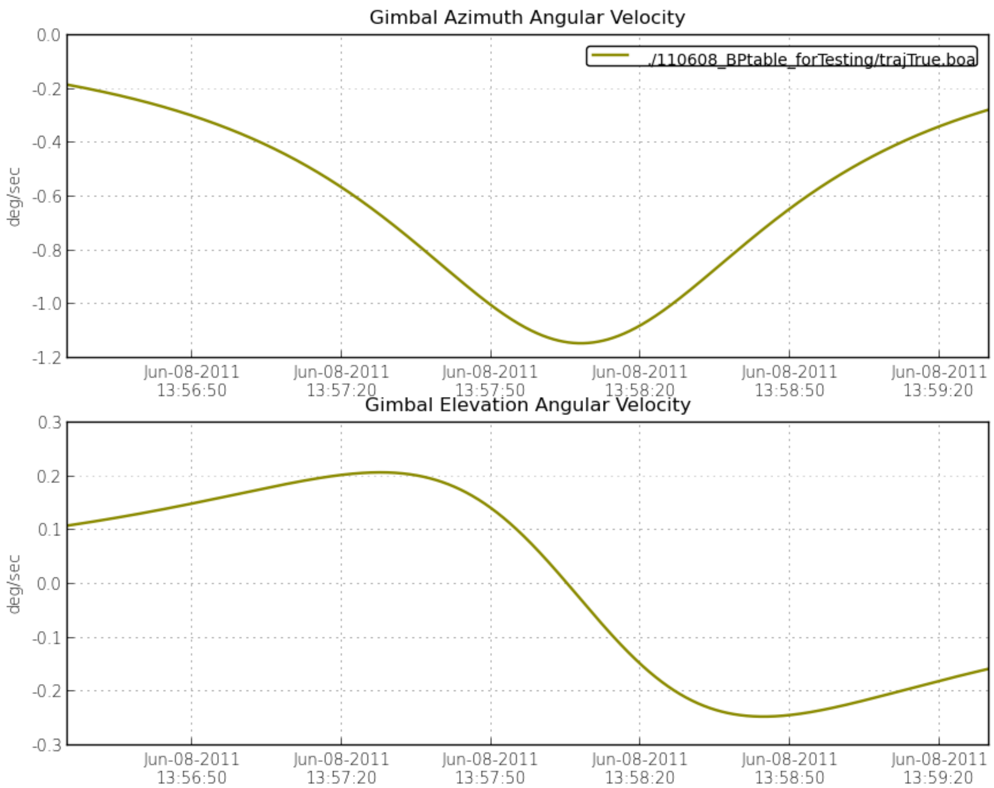

Figure 4: Gimbal Axis Angular Velocities During a Typical Pass

Acknowledgements

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References

[1] Oaida, B., Abrahamson, M., Witoff, R., Bowles-Martinez, J., Zayas, D., "OPALS: An Optical Communications Technology Demonstration from the International Space Station", 2013 IEEE Aerospace Conference, Big Sky, Montana, March 2-9, 2013.