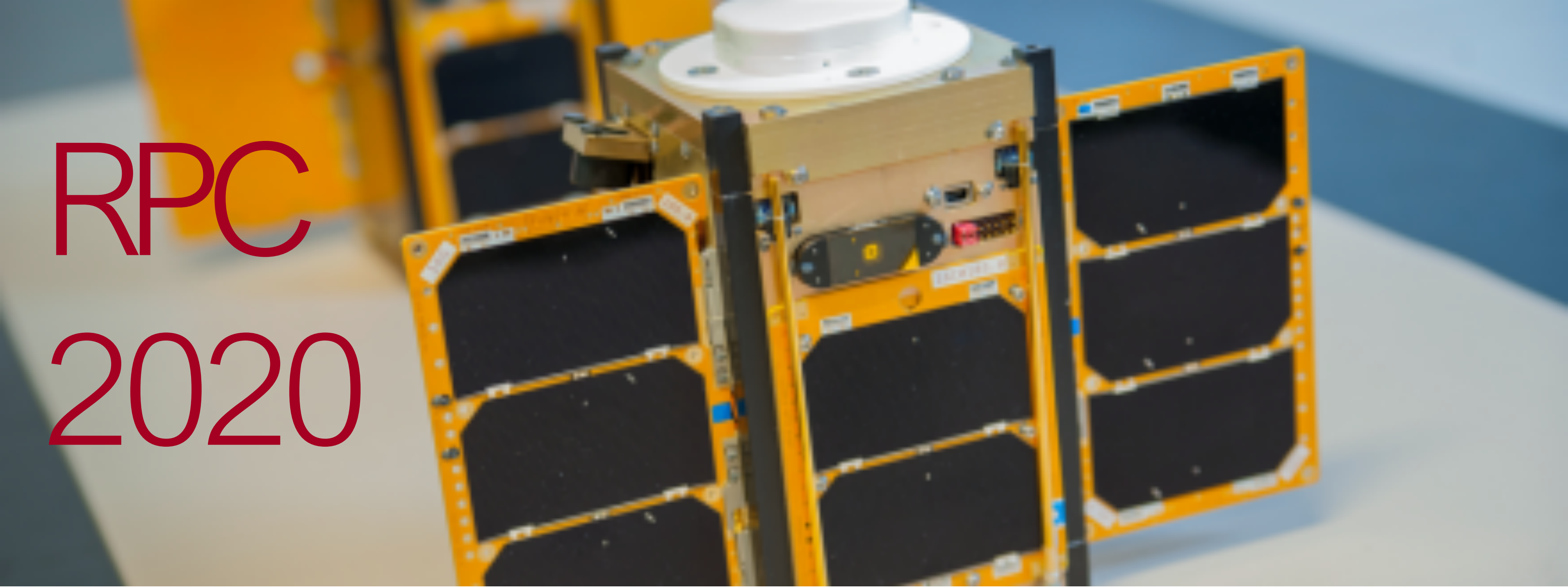

Virtual Research Presentation Conference

Inter-Satellite Ranging Techniques and Applications for Nanosatellite Platforms

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Program: SURP

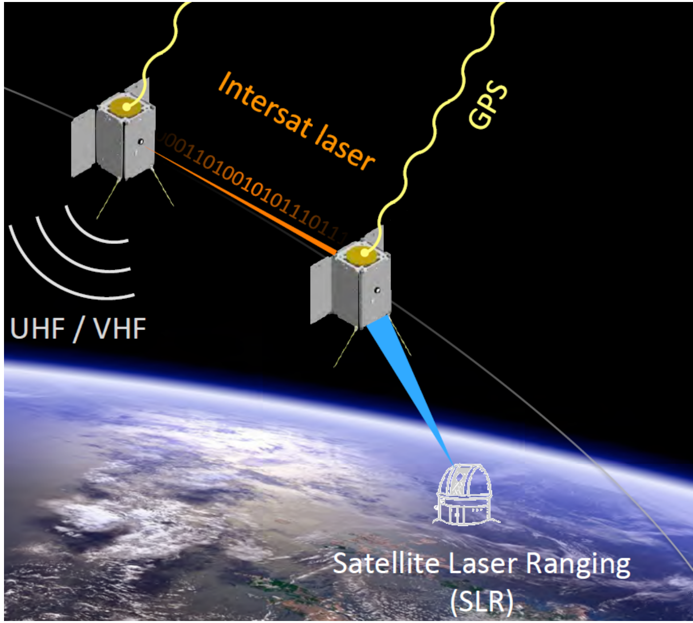
Assigned Presentation RPC-272

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

Global Navigation Satellite System (GNSS) based Precision Orbit Determination (POD) for satellites uses relative measurements of distance with respect to known GNSS satellite positions and velocities to estimate the overall state of the satellite. The state of the spacecraft being estimated includes position and velocity, but also stochastic clock corrections. Corrections to the orbital dynamics models being used for propagation, such as gravity parameters and atmospheric density, are estimated in precision applications. Corrections to the attitude profile or to the antenna Phase Center Variation (PCV) mappings may be co-estimated alongside those state and dynamic bias parameters in order to minimize overall orbit determination error. This SURP effort seeks to determine whether an overall gain can be made to the performance of a high-fidelity orbit determination scheme through the addition of relative intersatellite measurements between non-GNSS satellites in a constellation. If satellites in a constellation had cross-links yielding measurements of distance, what improvement over GNSS-only POD would this afford? This project develops a high-fidelity simulation and estimation environment in JPL's Monte software to assess the capabilities of nanosatellites with dual-frequency GNSS receivers to perform POD with GNSS only and quantifies gains to POD with crosslink observations.



Problem Description

a) Context: Nanosatellite constellations are becoming increasingly common in Low Earth Orbit, such as those put into place by Spire and Planet, to name a few. Typically, these satellites are not focused on POD, and often have single frequency L1 antenna and receivers, and usually do not perform robust multipath and antenna characterization prior to flight as these are unnecessary for their navigational needs.

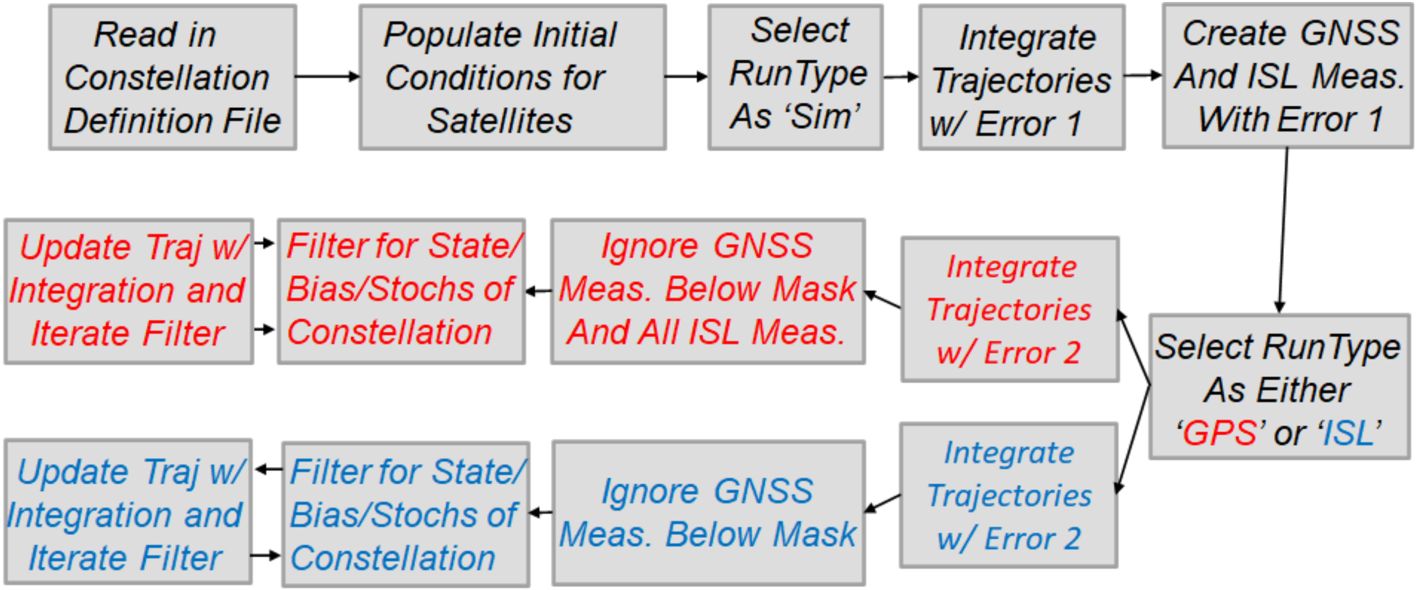
b) SOA: Most nanosatellite orbit determination is on the order of tens to hundred of meters [1,2]. If a science mission utilizing a nanosatellite platform needs better than this, a dual-frequency receivers with ground plane antennas could be utilized, but the nanosatellite platform is too small for choke-ring antennas [3]. Previous work by Psiaki [4,5] demonstrated that the dynamics of the intersatellite distances in a constellation contain information about the absolute position of the spacecrafts in the constellation, if the dynamics can be localized inertially (such as with higher order gravity). Previous publications by Davis and Gunter have explored, using low-fidelity simulations, the impact of intersatellite observations on POD capabilities of nanosatellite constellations [6,7].

c) Relevance to NASA and JPL: Improving the absolute and relative POD capabilities of nanosatellite constellations is enabling for a host of science missions, such as interferometry or gravity recovery. JPL's Monte software allows the authors to expand upon their previous studies to provide a more accurate assessment of the true gains afforded by inclusion of hardware on future nanosatellite constellation missions capable of observing these intersatellite measurements (such as through laser/radio methodologies).

Methodology:

a) Satellite Orbits and GNSS as well as ISL (Inter-Satellite Link) observations are simulated with appropriate noise realizations. Then those same orbits are estimated under perturbed dynamics using state of the art filtering techniques.

b) By including this new ISL observable, we are able to improve the relative and absolute POD of the nanosatellite constellation

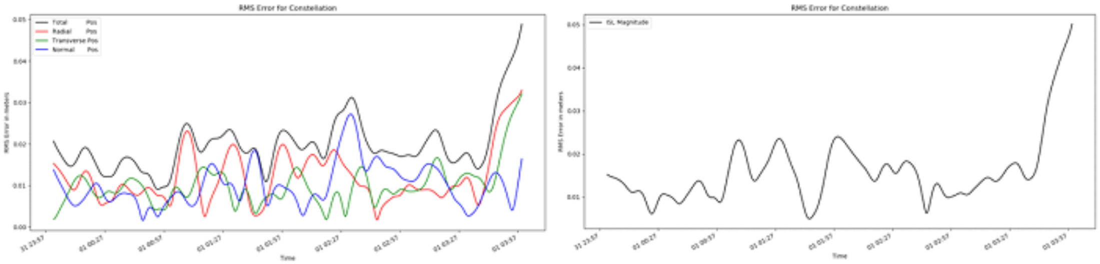


Results

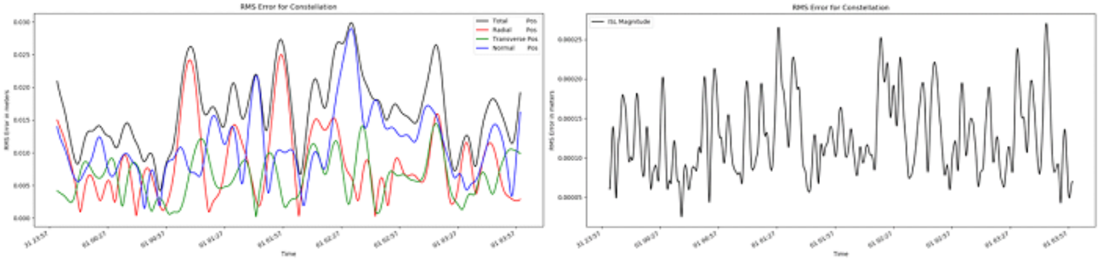
a) Accomplishments versus goals: We wanted to show that inclusion of additional inter-satellite link observables can improve absolute and relative POD for nanosatellite constellations. In the figures on the right, we show that, for constellation that is planar, we can improve the radial and transverse components of the POD for the constellation by over 30%, but that the normal component is not corrupted. Additionally, ISL magnitudes are improved over 99%

b) Significance: This may enable new nanosatellite science missions that need better POD

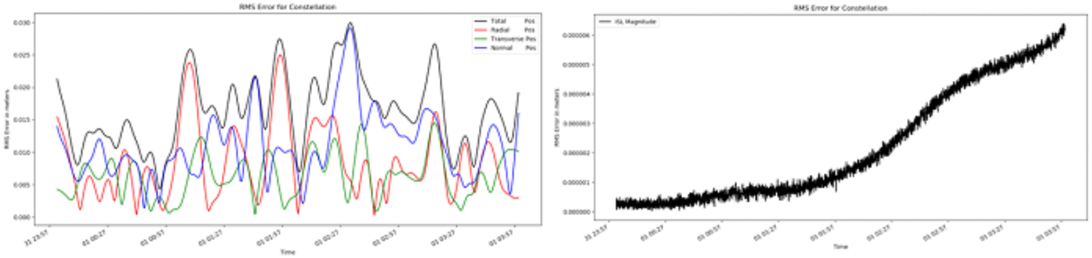
c) Next steps: Demonstrate science return with gravity recovery



GNSS Only RTN Position and ISL Magnitude Errors



GNSS + 1 mm ISL RTN Position and ISL Magnitude Errors



GNSS + 1 micron ISL RTN Position and ISL Magnitude Errors

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