National Aeronautics and Space Administration

Bias Compensated Inertial Navigation

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Program: FY22 R&TD Topics
Strategic Focus Area: Localization and Mobility

STIM300 IMU system being utilized

STIM300 on a rate table to measure impact of bias compensation

Objectives:

The objective of this research is to understand and improve JPL experience in inertial navigation accuracy. More specifically:

1) Generate algorithms that can simulate an IMU system suspended in a gondola under a Venus Balloon
2) Conduct a field test to acquire inertial navigation data
3) Reconcile IMU data from the field test with simulated IMU performance from Venus Balloon Simulation
4) Understand the achievable accuracy improvement by mechanically rotating the IMU to null out biases in the IMU
5) Write a conference paper

Background:

Many methods exist for position determination. These methods include GPS, celestial navigation, correlation to a terrain image, digital elevation mapping, magnetic maps, inertial navigation and pulsar navigation. In two particular environments position determination is very difficult: On a balloon inside a cloud or in a submarine. This is because external optical measurements are not possible. Also, position determination on places other than Earth is difficult because the magnetic field may not be strong or stable and no GPS satellites are available. Under these circumstances only one means of navigation is feasible: Inertial navigation. Within the last years, Phosphine has been discovered in the atmosphere of Venus. Some scientists believe it could be a biomarker. This discovery has initiated a massive interest in missions to Venus. In-situ analysis of the Venus atmosphere will require an airship/balloon/ballute type mission. A Venus balloon will be without communications for periods of up to 12 hours. Position estimation of such a airship/balloon/ballute will primary be based on inertial navigation.

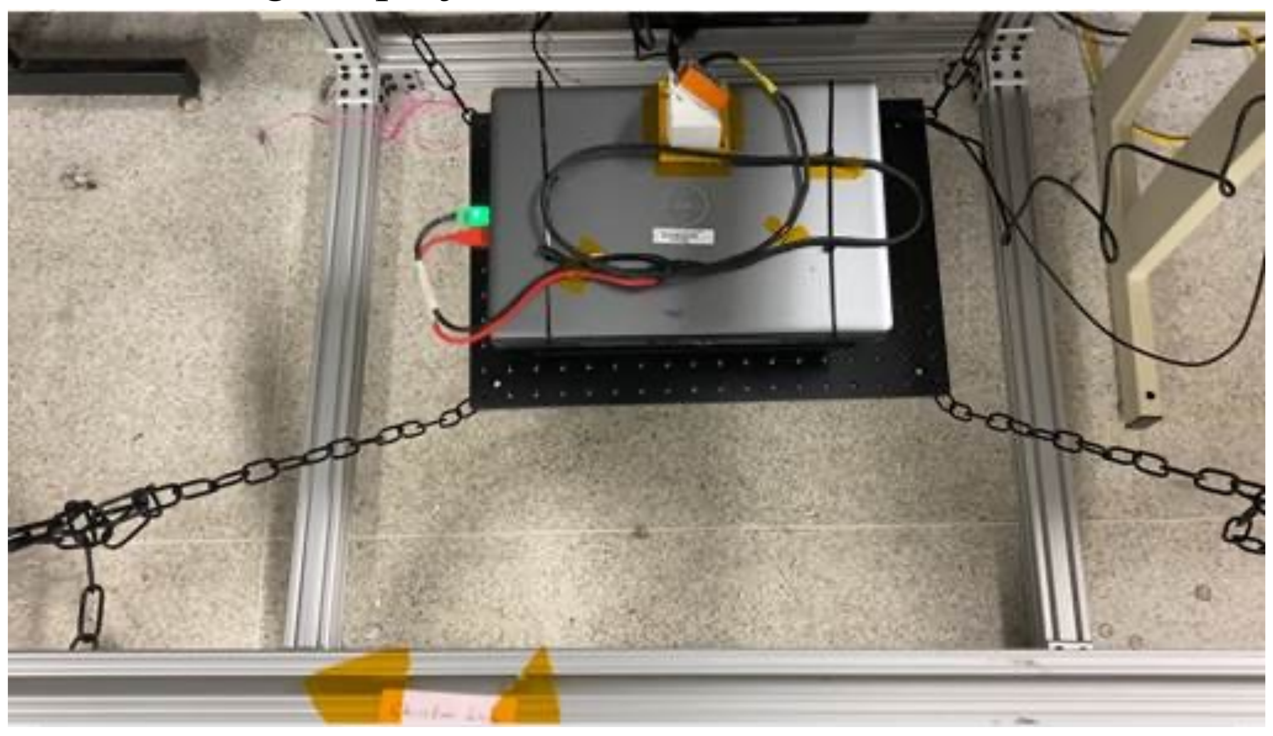
Approach and Results:

1) An initial simulation of the concept of mechanically rotating the IMU was performed. The simulation showed that improvements in the accuracy can be realized when the IMU is rotated. 2) A STIM300 IMU was procured. Initially, the plan was to procure an LN-200 IMU. However, due to supply chain issues, the delivery time had increased to 15 months when the proposal was funded. 3) The STIM300 was characterized on both a static test bench for 60 hours and on a rate table to understand the performance of the STIM300. 4) A field experiment setup was built for the STIM300. It consisted a suspended aluminum plate. The plate was suspended with metal chains inside a 4 feet aluminum cube. A battery driven data acquisition setup was constructed for the IMU. Also, the data acquisition system was mounted on a battery driven rotation stage. Also, a GPS logger was added. 5) The setup was mounted in a JPL minivan. It was then possible to log data with the IMU for periods of up to 8 hours driving on the freeway. This type of experiment is a “poor mans testbed/simulator for a Venus balloon” 6) A field test was conducted by acquiring more than 10 hours of data. More specifically, driving to Primm, Nevada (straight freeway) twice and driving highway 2 (curved road) with both IMU bias compensation enabled and not. 7) Analysis shows that a position estimation accuracy on 30 km (1 sigma) can be achieved after 6 hours assuming optimistic wind conditions. 8) A paper has been written for the 2023 IEEE Aerospace conference. A future New Frontiers proposal for a Venus Balloon can reference this paper to avoid that JPL gets a weakness in this area.

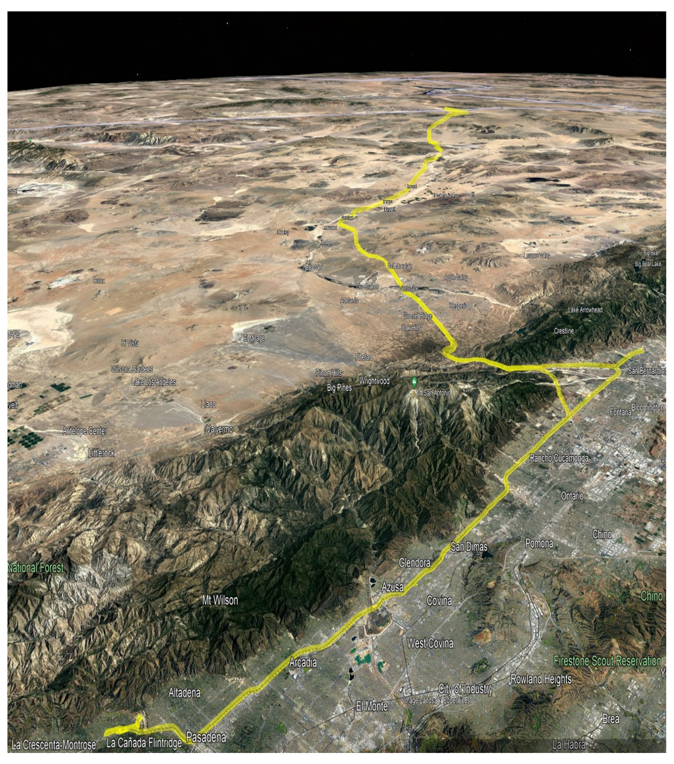
Significance/Benefits to JPL and NASA:

Inertial navigation will be used for position determination for future balloon missions to Venus and future missions to the ocean of Europa. JPL does not have a lot of experience in inertial position determination. The RTD increases the experience level of several GNC analysts in section 343. Due to the discovery of phosphine in the atmosphere of Venus, it is expected that a solicitation for a Venus Balloon type mission will come out within a few years (at one point, it was planned to be included in the FY23 New Frontiers solicitation). This type of mission will require position estimation for the science payload. Utilizing, low mass technology will result in a system with very poor performance. Therefore, this RTD investigates the idea of mechanically rotating the IMU to increase the accuracy. Also, a conference paper will be published on this topic. This work will make it possible to confidently make a system design for position estimation and make reference to a JPL published paper. This will avoid JPL getting a weakness in a future proposal and increase JPL chance of winning the project.

JPL Minivan utilized as a poor man’s “Venus balloon simulator” by driving on the freeway.



Suspended STIM300, mounted on top of a notebook computer. The notebook computer is mounted on a rotation stage (not visible under the notebook). This is mounted on a suspended aluminum plate.



GPS plot of a field trip to Primm with the JPL minivan.

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Publications:

Scott Ploen, Jack Aldrich, David Bayard, Leonard Dorsky, Anup Katake, Edward Konefat, Carl Christian Liebe, Joel Shields: Bias Compensated Inertial Navigation for Venus Balloon Missions, to be submitted to the 2023 IEEE Aerospace Conference, Big Sky, Montan, 4-11 March 2023

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