TEST REPORT

AERIAL MAPPING

VN-200 and VN-210 Aerial Triangulation Report Summary

INTRODUCTION

In May of 2017, an independent test was conducted by Professor Jim Bethel and Mr. Ron Benziger of Purdue University in West Lafayette, Indiana, USA. The purpose of the test was to perform an independent validation of the performance specifications of VectorNav Technologies' VN-200 and VN-210 GPS-Aided Inertial Navigation Systems (GPS/INS). Throughout the flight test, the Purdue team logged data from two VN-200 and two VN-210 units while also recording images from an aerial mapping camera. Data logged from the VectorNav sensors was compared to high-accuracy, post-processed position and attitude data calculated from the camera images using a technique known as photogrammetric triangulation. This Test Report summarizes the findings of the flight test.

TEST DESCRIPTION

The aircraft used in this test was a Cessna 310, operated by Williams Aerial of South Bend, Indiana. Two VN-200 and two VN-210 INS units were installed to a precision milled aluminum plate, and each INS unit was connected to a Tallysman TW2410 GNSS antenna. The setup also included a calibrated Leica RC-30 aerial mapping camera, which is able to determine the position of image points in the focal plane to an accuracy of 10 micrometers. The Leica RC-30 features a 6 inch (~15 cm) focal length, wherein a single ray is capable of being measured with an uncertainty of less than 0.004 degrees. Hundreds of these rays were measured over multiple images from the flight and combined with ground control points known to 2 cm to determine the attitude of each photograph.

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TEST RESULTS

VN-210 GNSS-Aided Inertial Navigation System

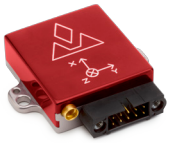
Heading (Dynamic)

Specification	Test Result
< 0.1 ° RMS	0.02 °

Pitch/Roll (Dynamic)

Specification	Test Result
< 0.03 ° RMS	0.02 °

VN-200 GPS-Aided Inertial Navigation System



Heading (Dynamic)

Specification	Test Result
< 0.3 ° RMS	0.15 °

Pitch/Roll (Dynamic)

Specification	Test Result
< 0.1 ° RMS	0.04 °

VectorNav Products Tested

VN-200 GPS-Aided INS & VN-210 GNSS-Aided INS

Testing Platform

Cessna 310

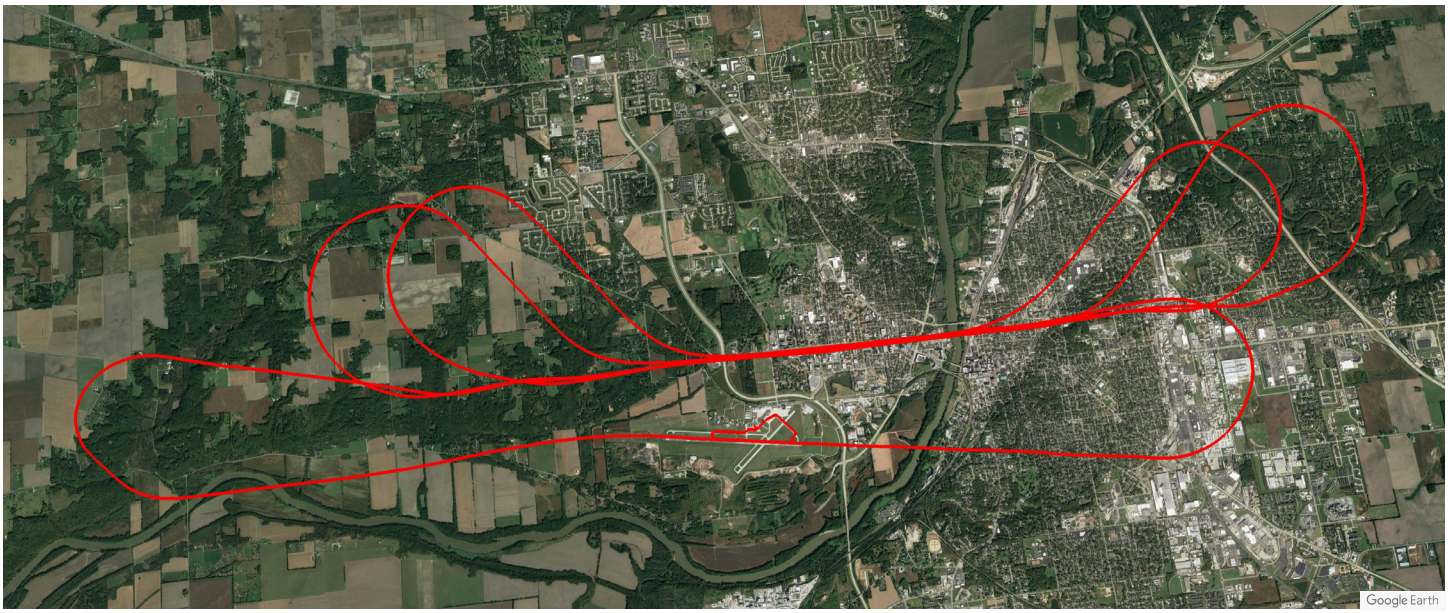
Reference System

Leica RC-30 Aerial Mapping Camera

Testing Location & Date

South Bend, Indiana, USA, March 10, 2017

The aircraft was flown at an average velocity of 86 m/s (192 mph) and at an average height of 456 meters (1496 feet). The VN-200s and VN-210s were mounted to the top of the camera and synchronization of the two systems was achieved by using a "mid-exposure pulse" generated by the camera and timestamping it with an auxiliary GPS timing device. Post processed photogrammetric attitude and position data could then be compared to timestamped INS position and attitude data from the VN-200 and VN-210. Each exposure event/picture contained 23 ground control points and approximately 125 tie points. Over the course of the 11-minute flight 16 photographs were captured via repeated passes over the control field to conduct the aerial triangulation.



The image above shows the flight path taken by the aircraft during the data acquisition stage of the flight.

RESULTS

The table below shows the standard deviation of attitude errors across the 16 images that were taken. Boresight misalignment (the mounting angle difference between the camera and INS units) produced a constant offset/bias, which were subtracted.

VN-210 and VN-200 RMS Attitude Error

	VN-210 (unit A)	VN-210 (unit B)	VN-200 (unit A)	VN-200 (unit B)
Roll	0.02 °	0.02 °	0.02 °	0.06 °
Pitch	0.02 °	0.02 °	0.04 °	0.03 °
Yaw	0.01 °	0.03 °	0.18 °	0.12 °

Based on the data presented above the VN-210 produced an average Pitch/Roll accuracy of 0.02° (under the specified < 0.03° RMS) and average heading accuracy of 0.02° (under the specified <0.1° RMS). The VN-200 produced an average Pitch/Roll accuracy of 0.04° (under the specified 0.1° RMS) and average heading accuracy of 0.15° (under the specified 0.3° RMS).

Position data has not been presented in this summary. Each of the VN-200 and VN-210 specify 2.5 RMS position error on each of the horizontal and vertical axes. For airborne applications such as this, when having a continuous, clear view of the sky, using a compatible GPS antenna and utilizing SBAS, typical errors in the horizontal and vertical position solution will be 1-2 meters RMS for the VN-200 GPS-Aided INS and 0.6-0.8 meters RMS for the VN-210 GNSS-Aided INS.

For a copy of the full report please contact VectorNav at sales@vectornav.com.

A special thank you to Professor Jim Bethel and Mr. Ron Benziger of Purdue University for their cooperation and for making these tests possible.

ABOUT VECTORNAV

VectorNav Technologies is a leading developer and manufacturer of high performance inertial navigation systems using the latest in MEMS sensor and GPS/GNSS technology. Since its founding in 2008, VectorNav has provided systems integrators in the Military, Aerospace, Marine, and Robotics industries with inertial navigation solutions with best-in-class price to performance ratios.

VectorNav Technologies is headquartered in Dallas, Texas, USA and is an AS9100 certified company.

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