NovAtel's
SPAN® GNSS/INS with the Honeywell HG1900 and HG1930 MEMS IMUs

Performance Analysis—April 2012

Abstract

NovAtel's SPAN GNSS/INS products are used to provide precise position, velocity and attitude across many applications. Increasingly applications require smaller and lighter components for use in compact vehicles or embedded within systems such as cameras or communication devices.

Until recently, accurate navigation using inertial technology was only possible with high end ring laser or fiber optic gyroscope technology. Today, Micro Electromechanical System (MEMS) technology has improved significantly with some sensors providing performance approaching that of more traditional gyro technologies.

The HG1900 and HG1930 are MEMS gyro-based Inertial Measurement Unit (IMUs) suitable for various commercial and military guidance and navigation applications.

Small, robust, low power and affordable, the HG1900 has a performance range consistent with tactical missile and smart munition requirements (Honeywell Aerospace 2010).

The HG1930 is a small, economical MEMs IMU providing tactical grade performance for unmanned vehicles and other commercial and or military guidance systems.

About SPAN

SPAN™ technology tightly couples NovAtel's OEM precision Global Navigation Satellite System (GNSS) receivers with robust IMUs to provide continuously available, 3D position, velocity and attitude—at data rates up to 200 Hz. When combined, the two navigation techniques augment and enhance each other with the absolute position and velocity accuracy of the GNSS compensating for the errors in the IMU measurements that occur over time. The stable relative position of the INS is used to bridge times when the GNSS solution is degraded or unavailable such as in a busy port environment.

While data for this performance analysis was collected in real-time, NovAtel's SPAN technology offers post-processing capabilities through its Waypoint® software. SPAN products allow for the collection of raw GNSS and IMU measurement data for later use. Inertial Explorer software uses the stored measurement data, post-mission, to generate a more accurate solution than is possible in real-time.

Test Overview

This paper contains results from the ground navigation testing of the Honeywell HG1900 and HG1930 MEMS IMUs within NovAtel's SPAN system. Real-time position, velocity and attitude prove comparable with systems using heavier and larger ring laser and fibre optic gyro IMUs. Although the HG1900 out performed the HG1930, the size advantages of the HG1930 need to be weighed against the importance of the navigation performance for specific applications.

Test Equipment Overview

For testing, IMUs were controlled using NovAtel's MEMs Interface Card (MIC) to provide the necessary regulated power inputs, decode the binary message stream and apply a precise time to each IMU measurement. The time stamped data was used along with the GNSS measurements to compute the integrated GNSS/INS solution onboard a NovAtel OEMV® GNSS receiver. The solution was available in real-time through the receiver peripheral devices.

Real-time data was compared to an Inertial Explorer® post processed solution from a navigation grade IMU running at the same time.

Model Information

1. HG1900 (CA29 model)
2. HG1930 (AA99 model) - 20 150-10-300 model
3. OEMV3-RT2-C
4. GPS-703-GGG Antenna

Product Highlights

HG1900

- Small form factor
- Economical
- Low power
- 100 Hz data rate
- Commercial or military applications

Figure 1: HG1900

Table 1: HG1900 IMU Specifications

Dimension	92.7 x 79.1 mm
Weight	<460 g
Power Consumption	<3 W
Gyro Rate Range	±1000 deg/s
Gyro Bias	5 deg/hr
Gyro Scale Factor	150 PPM
ARW	0.09 deg/√hr Max
Accel Range	±30 g
Accel Bias	1 mg
Data Rate	100 Hz

HG1930

- Small form factor
- Economical
- 100 Hz data rate
- Commercial or military applications

Figure 2: HG1930

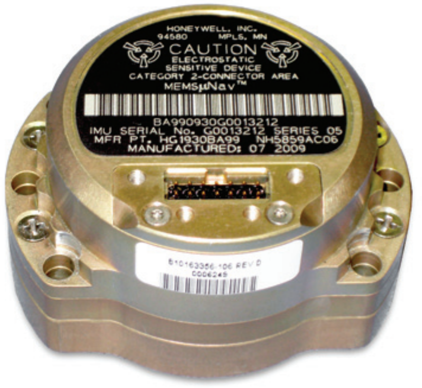


Table 2: HG1930 IMU Specifications

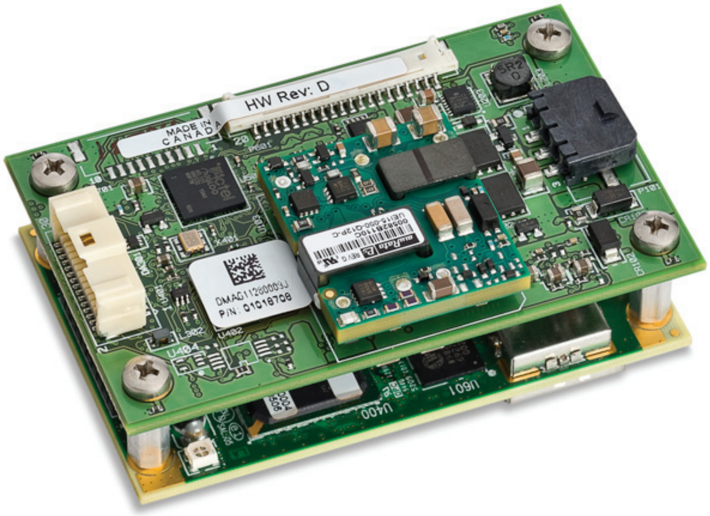
Dimension	65 max dia. x 36 mm ht.
Weight	200 g
Power Consumption	<3 W
Gyro Rate Range	±1000 deg/s
Gyro Bias	20 deg/hr
Gyro Scale Factor	300 PPM
ARW	0.125 deg/√hr Max
Accel Range	±30 g
Accel Bias	5 mg
Data Rate	100 Hz

Table 3: OEMV1-DF + MIC Specifications

Table 3 and Figure 3 show the current lightest weight board combination available to use SPAN. This test occurred before these were available, but SPAN performance is the same between the different OEMV boards.

Dimension	75.1 x 45.7 x 19.5 mm
Weight	21.5 g (V1DF) + 31 g (MIC)
Power Consumption	5.6 W (HG1900 with MIC and V1DF in 12 V stacked configuration)
Channels (when configured for SPAN operation)	10 GPS L1/L2 2 SBAS
Time Accuracy	20 ns RMS
Peripherals	1x USB, 1x LVTTL, 1 x IMU port

Figure 3: NovAtel OEMV1-DF Receiver with MEMS Card



Test Methodology

Testing was performed using both the HG1900 and HG1930 IMUs in two different configurations. One test was conducted in single point mode with no GNSS aiding sources, such as Real-Time Kinematics (RTK). In the second test, RTK corrections were input to the system in real-time from a stationary NovAtel base station.

To provide a truth solution for testing, a navigation grade IMU was installed in the vehicle. The raw IMU and GNSS data from the navigation grade system was post processed to provide the control for the test. Due to the quality of the control system, relative to the MEMS devices, differences between the two solutions are considered to be navigation errors in the MEMS system.

Table 4: Control IMU Performance Specifications

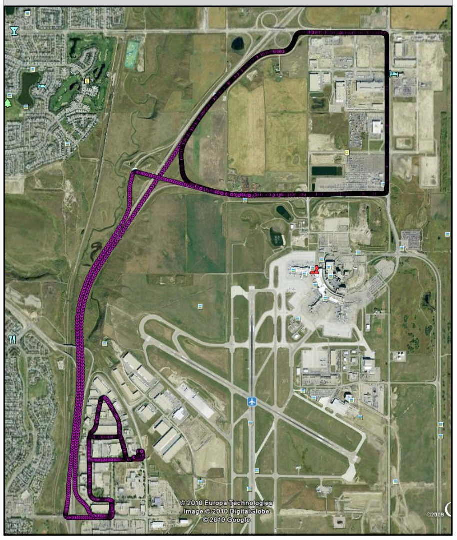
Gyro Bias	0.004 deg/hr
Gyro Scale Factor	5 PPM
ARW	0.0025 deg/√hr
Accel Bias	0.03 mg
Accel Scale Factor	100 PPM

Test Area

Testing took place in Calgary, Alberta. The distance travelled during testing was a 20 km loop (shown in **Figure 4**) over a period of 1.5 hours The base station was located within 10 km of the test site.

Tests were performed under conditions with relatively good views of the GPS satellites. This scenario is similar to the expected satellite visibility in an airborne environment.

Figure 4: Test Area-Calgary, AB



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Test Results

The plots show the performance for the SPAN real-time navigation solution using the HG1900 and HG1930 IMUs when operating in unaided single point mode followed by RTK mode performance. The mean attitude errors are not provided because the control IMU and test IMUs were not precisely aligned to each other. The offset in the attitude differences is due to this physical misalignment. Error numbers were obtained by differencing real-time HG1900 and HG1930 results with post processed data.

Figure 5: Single Point HG1900 SPAN Position Error

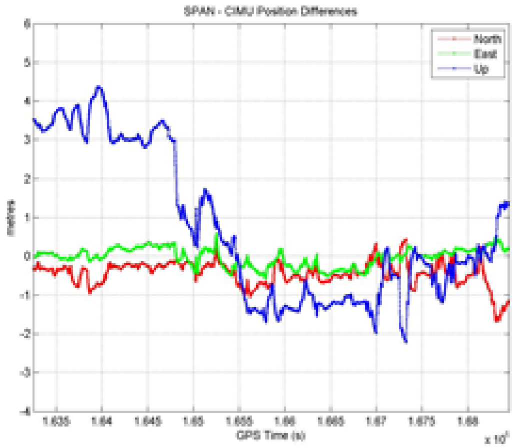


Figure 6: Single Point HG1930 SPAN Position Error

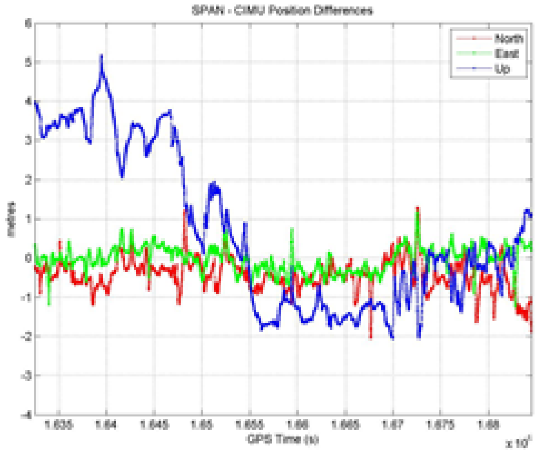


Figure 7: Single Point HG1900 SPAN Velocity Error

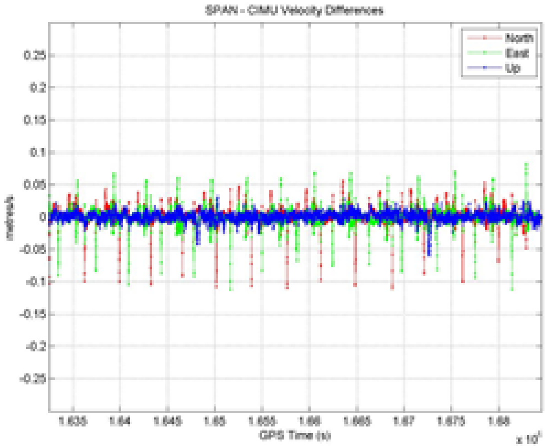


Figure 9: Single Point HG1930 SPAN Velocity Error

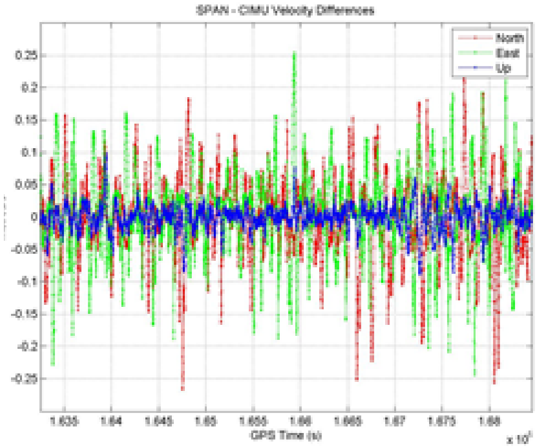


Figure 8: Single Point HG1900 SPAN Attitude Error

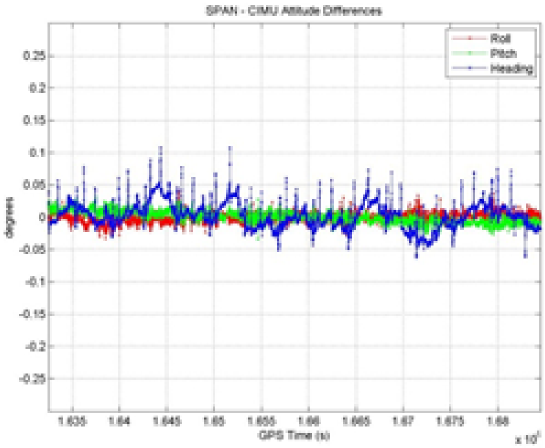


Figure 10: Signle Point HG1930 SPAN Attitude Error

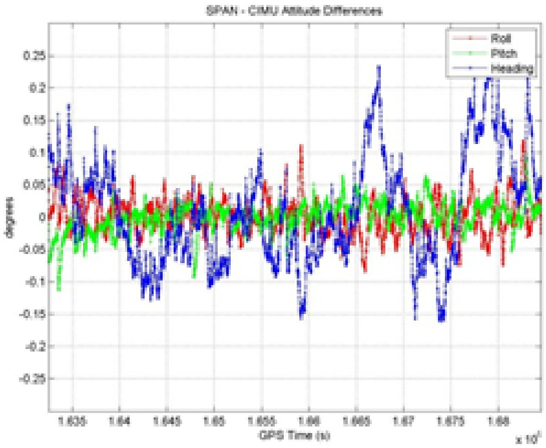


Figure 11: RTK HG1900 SPAN Position Error

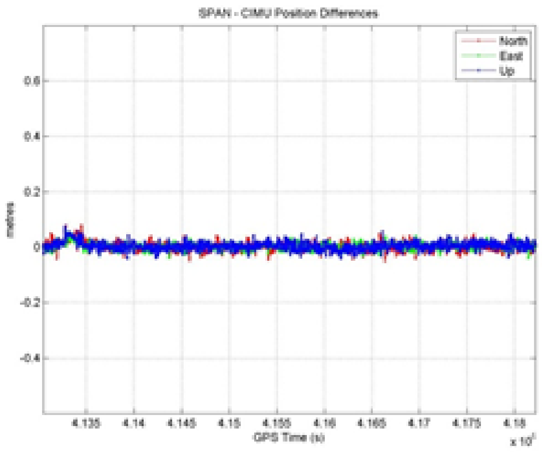


Figure 12: RTK HG1930 SPAN Position Error

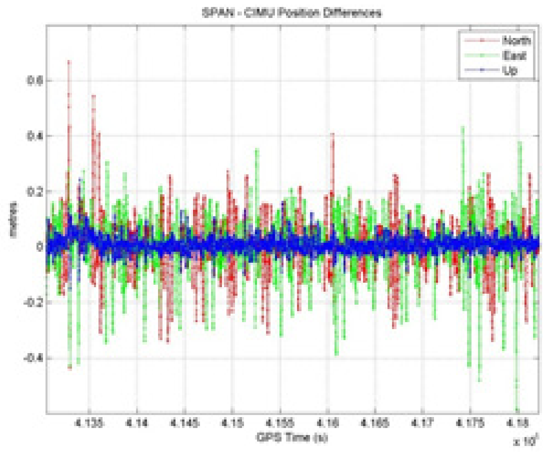


Figure 13: RTK HG1900 SPAN Velocity Error

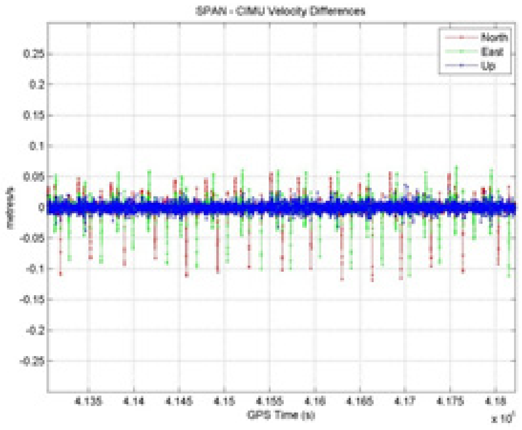


Figure 14: RTK HG1930 SPAN Velocity Error

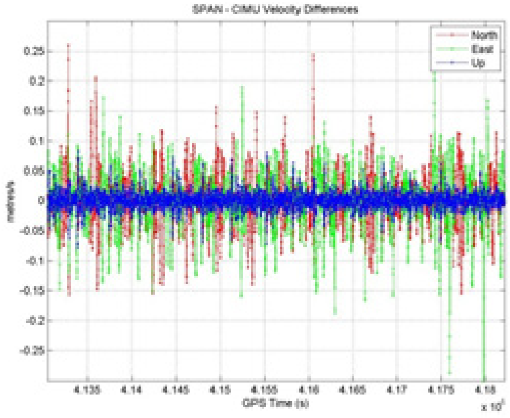


Figure 15: RTK HG1900 SPAN Attitude Error

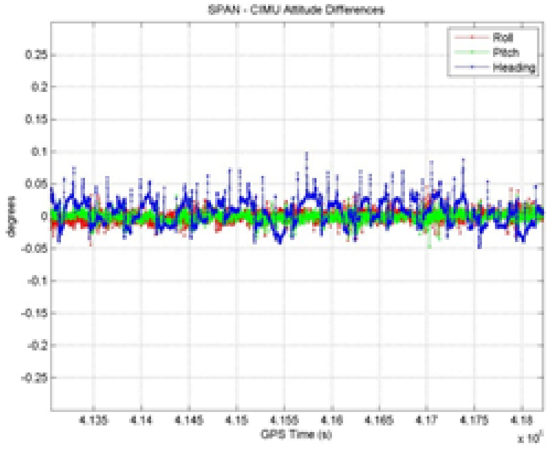
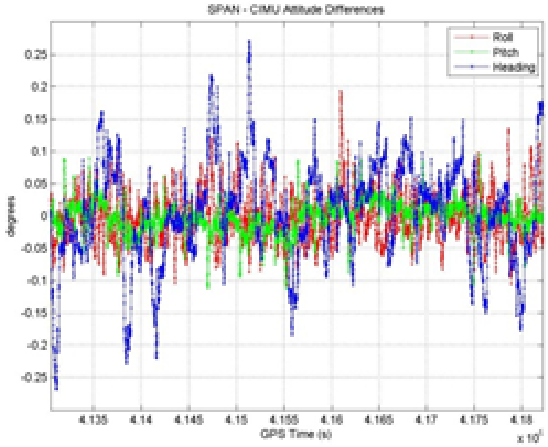


Figure 16: RTK HG1930 SPAN Attitude Error



Performance

The HG1900 and HG1930 IMUs, when integrated with SPAN, provide accurate position, velocity and attitude that is useful for many navigation and pointing applications. In both positioning modes the HG1900 outperforms the HG1930 in position, velocity and attitude performance. As expected, position accuracy is significantly improved by using RTK corrections, but the attitude for both IMUs gave similar Root Mean Squared (RMS) performance regardless of GNSS positioning mode. Velocity was marginally improved by operating in RTK mode versus single point.

Specifications and SPAN performance for the larger and heavier ring laser HG1700 are provided in the following tables. In testing, the HG1900 and HG1700 delivered equivalent performance. The HG1930 performance was slightly lower but does offer a size and weight advantage over the HG1900.

Table 5: Single Point HG1900 SPAN Summary

Errors	3D Pos. (m)	3D Vel. (m/s)	Roll (deg)	Pitch (deg)	Heading (deg)
RMS	2.14	0.02	0.007	0.009	0.030
Mean	0.68	0.002	N/A	N/A	N/A

Table 6: Single Point HG1930 SPAN Summary

Errors	3D Pos. (m)	3D Vel. (m/s)	Roll (deg)	Pitch (deg)	Heading (deg)
RMS	2.21	0.09	0.028	0.023	0.084
Mean	0.80	0.006	N/A	N/A	N/A

Table 7: RTK HG1900 SPAN Summary

Errors	3D Pos. (m)	3D Vel. (m/s)	Roll (deg)	Pitch (deg)	Heading (deg)
RMS	0.025	0.02	0.008	0.007	0.020
Mean	0.006	<0.001	N/A	N/A	N/A

Table 8: RTK HG1930 SPAN Summary

Errors	3D Pos. (m)	3D Vel. (m/s)	Roll (deg)	Pitch (deg)	Heading (deg)
RMS	0.130	0.06	0.038	0.025	0.078
Mean	0.013	0.002	N/A	N/A	N/A

Table 9: HG1700 SPAN Performance

RMS Errors	3D Pos. (m)	3D Vel. (m/s)	Roll (deg)	Pitch (deg)	Heading (deg)
SP	1.200	0.02	0.010	0.010	0.023
RTK	0.020	0.02	0.010	0.010	0.021

Table 10: HG1700 IMU Specifications

Dimension	168 x 195 x 146 mm with enclosure
Weight	4.5 kg with enclosure
Power Consumption	8 W typical
Gyro Rate Range	±1000 deg/s
Gyro Bias	1 deg/hr
Gyro Scale Factor	150 PPM
ARW	0.125 deg/√hr
Accel Range	±50 g
Accel Bias	1 mg
Data Rate	100 Hz

Conclusion

The HG1900 and HG1930 IMUs offer size and weight advantages over IMUs using different gyro technologies. The HG1900 performance during testing compares favorably to performance experienced with the HG1700 Ring Laser Gyro (RLG) product. Although the HG1930 performance is less than the HG1900 and HG1700, the size and weight advantages of the HG1930 must be weighed against the lower grade navigation solution performance.

For more information on the NovAtel range of SPAN systems, including non-ITAR tactical grade IMU's, please visit:

http://www.novatel.com/products/span-gnss-inertial-systems/

April 2012