Crescent®
Receiver Technology

Crescent OEM White Paper

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Hemisphere GPS®

With offices in Kansas City, Hiawatha, Calgary and Scottsdale, Hemisphere GPS® is a global leader in designing and manufacturing innovative, cost-effective, high quality GPS products for a variety of rapidly growing commercial and consumer markets.

Our GPS and differential GPS (DGPS) products, sold in more than 50 countries worldwide, play critical roles in industry by ensuring more accurate navigation, improvements in productivity and safety, and savings in cost and time.

To further our position in the growing market of GPS products, Hemisphere has developed its own ASIC technology. Without the limitations previously imposed by using an off-the-shelf chipset, we are now positioned to offer our customers a wider variety of products with expanded functionality and improved performance.

Introducing the Crescent® Receiver: Foundation for the future

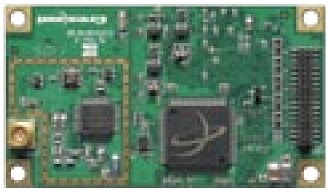
The Crescent® Receiver is a high-accuracy GPS module capable of providing sub-meter accuracy when differentially corrected with SBAS or external corrections.

Designed and developed by the Research & Development team in our Scottsdale, Arizona office, Crescent incorporates Hemisphere's own ASIC technology. Owning our intellectual property allows us to develop future products that are not restricted by the limitations of other chipsets.

Crescent also employs Hemisphere's COAST™ technology in order to maintain consistent, accurate positioning during periods of differential signal loss. In contrast to traditional receivers, where accuracy will degrade with increasing age of corrections, COAST uses advanced algorithms to model the change in errors that occur during differential signal outages. The user is able to specify the maximum age of corrections that can be used, and our field testing has shown that old correction data can be used for up to 40 minutes without significantly affecting accuracy. This provides improved tolerance over competing products with respect to signal loss due to noise or line-of-sight blockage.

Crescent will initially be integrated into Hemisphere's current line of products because it is fully backwards compatible with our SX-1™ GPS board. In mid-2005 the receiver will be available as an OEM board, and integrators will immediately be able to benefit from its enhanced performance and capabilities. As well, any current integration incorporating the SX-1 will be compatible mechanically and electrically. There will also be a secondary version, which will be plug-in compatible with the NovAtel SUPERSTAR II™ receiver.

Further development will continue to create the next generation of products that will take full advantage of Crescent functionality. With its improved code phase measurements, and improved multipath mitigation, users will be able to notice a number of performance improvements, including improved accuracy and faster setting times. The Hemisphere-developed ASIC also has the ability to use multiple front ends, enabling sharing of information between antennas and eliminating the need for multiple receivers, which will significantly benefit future introductions to the Vector GPS Compass line of products. Accompanying this new GPS board will also be firmware which will offer several upgrade options.



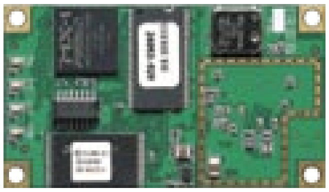


Figure 1: Crescent® OEM Board

Available Options

The standard version of the Crescent receiver will have a 1Hz available output rate, and this will be upgradeable to 2 Hz, 10 Hz or 20 Hz.

Customers can improve their positioning capabilities with:

- e-Dif®: Extended differential Operation: The receiver module is designed to operate with Hemisphere-patented e-Dif software. e-Dif is an optional mode in which the receiver can perform with differential-like accuracy for extended periods without the expense or uncertainty of an external differential service. It models the effects of ionosphere, troposphere, and timing errors for extended periods by computing its own set of pseudo-corrections. e-Dif may be used anywhere geographically and is especially useful where SBAS networks have not yet been installed, such as South America, Africa, Australia, and Asia.

The positioning performance of the receiver unit is dependent upon the rate at which the environmental modeling of e-Dif and the environmental errors diverge. The more that e-Dif is able to model the errors correctly, the longer that e-Dif will provide reliable, accurate positioning. The accuracy of positioning will have a slow drift that limits use of e-Dif to approximately 30 to 40 minutes, however, it depends on how tolerable your application is to drift, as e-Dif can be used for longer periods. Our testing has shown that accuracy will often be better than 1.0 m virtually 95% of the time after 30 minutes of e-Dif operation.

- L-Dif™: Local differential Operation: Local differential is a proprietary Hemisphere GPS method where a specialized set of messages are relayed between two Crescent receivers. Because the messages transmitted are in a proprietary format, two Crescent receivers are necessary for local differential operation.

A base receiver is established on a site of known coordinates, which then broadcasts corrections to a rover unit. As further detailed in the performance section of this document, testing has resulted in positioning accuracy of sub-10cm.

- RTK: Real Time Kinematic Positioning: Similar to conventional DGPS, RTK uses a base station (or a network of base stations) installed at locations of known coordinates. Measurements in real time are taken at both the rover and base station, however, in addition to the C/A code-based range measurement, the carrier phase is also measured. The additional measurement of the carrier phase is used to compute the number of carrier cycles between the rover antenna and each of the satellites in view.

Resolving the ambiguous number of carrier waves to each satellite (called the ambiguity for each satellite) is performed by a proprietary algorithm within the receiver. Software options for both base station and rover unit capability will be offered in conjunction with both the Crescent OEM board and integrated products.

Performance

The enhanced performance of the Crescent receiver is due to improved correlator design, code phase measurements and multipath mitigation, and can be illustrated in a number of ways.

Following are the results of testing performed by both our Calgary and Scottsdale offices that serve to simulate real-world situations.

Local Differential (L-Dif)

Tests were performed at our Scottsdale, Arizona office using a baseline length of 4 km. The results over both a 1 hour and 24 hour time period are plotted below, giving positioning errors in latitude and longitude with respect to a known point.

The first of these tests monitored the position of the remote receiver over the course of one hour, and demonstrated a steady position with latitude and longitude variations below 10 cm. The second of these tests monitored the remote over the course of a full day, and demonstrated discrepancies within a 20 cm range.

Figure 2: Position Error using Local Differential (1 hour total)

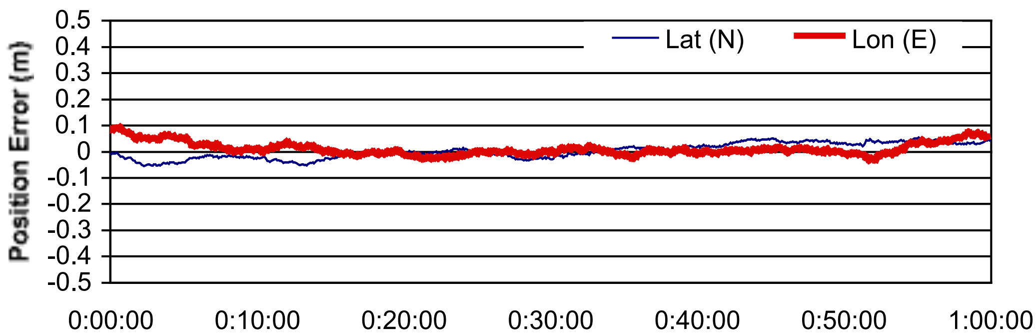
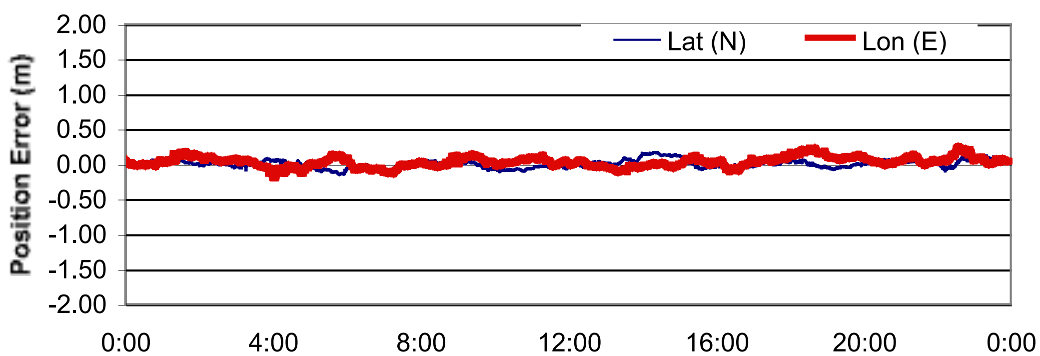


Figure 3: Position Error using Local Differential (24 hours total)



Autonomous Comparison

In this test, we compared three different receivers, one of which was the Crescent receiver. The other two are well-known brands in the GPS industry. This test was performed at our Calgary office at 51°N over 24 hours. All three receivers were set not to use any source of differential corrections to augment the GPS position. This was a zero baseline test, as the signal from a single CDA-3™ antenna was split three ways to eliminate any differences in the signal being fed to the receivers.

From the northing-easting scatter plot below, you can see that brand X did the worst, brand Y was in the middle and Crescent did the best in terms of relative accuracy.

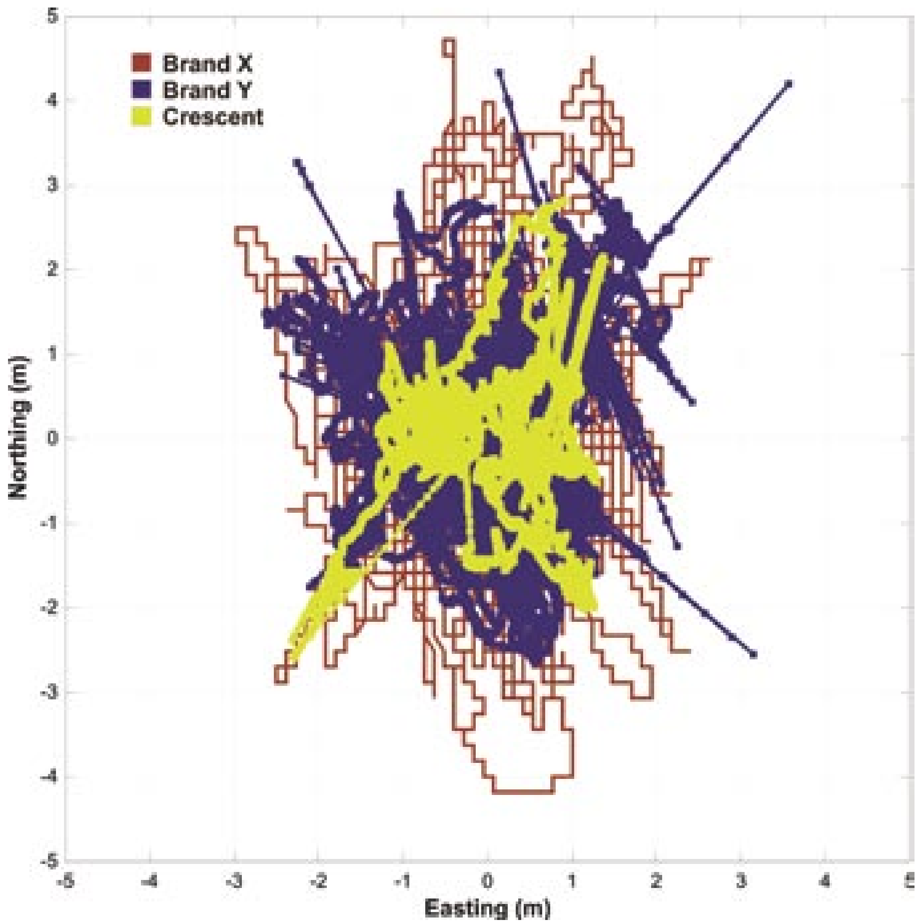


Figure 4: Autonomous Positioning Accuracy Comparison

Receiver	Relative Accuracy (95%)
Crescent®	2.133 m
Brand X	2.938 m
Brand Y	2.427 m

WAAS

Two tests were performed using WAAS as the differential source.

In the first test, we recorded data over a period of one hour to examine the short-term stability, which is important in agricultural applications. As illustrated below, the position is fairly constant, with 95% relative accuracy of 15 cm in both latitude and longitude.

In the second test, we collected a full dataset over 24 hours to demonstrate the long-term accuracy. The 95% relative accuracy of the latitude and longitude during this test was 50 cm.

Figure 5: Position Error using WAAS (1 hour total)

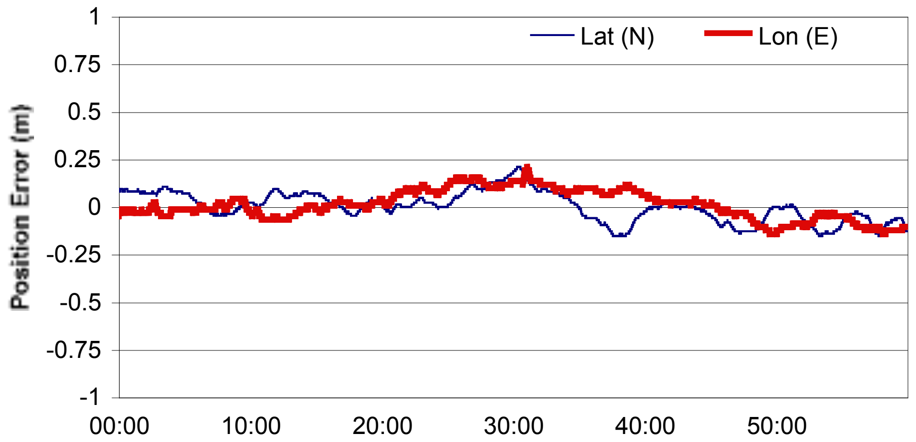
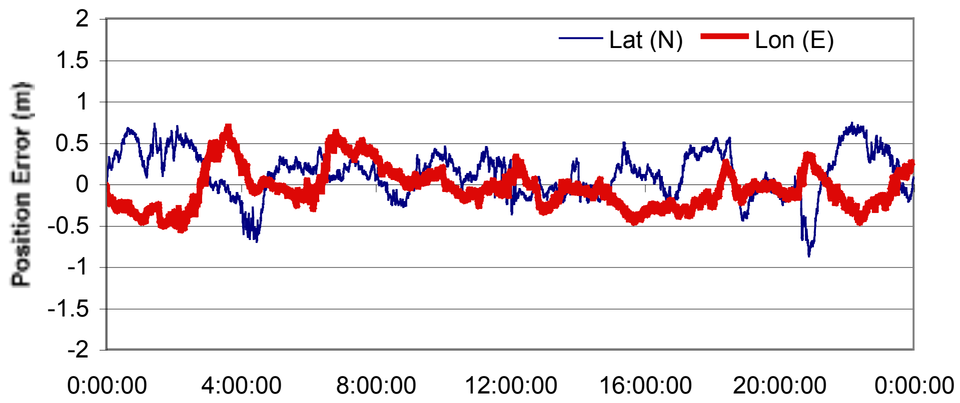


Figure 6: Position Error using WAAS (24 hours total)



Settling Time

The following test was done using code only measurement to show the settling time of the receiver which demonstrates how quickly a reliable position can be acquired. As you can see from the plot of position error over time for a total of 10 minutes, it took the Crescent less than 100 seconds to settle to less than a half meter of accuracy. Upon loss of GPS lock, it took the receiver less than 20 seconds to return to the original accuracy level of 0.5 meters. This can be seen in the second plot below.

Figure 7: Acquisition Time after Startup

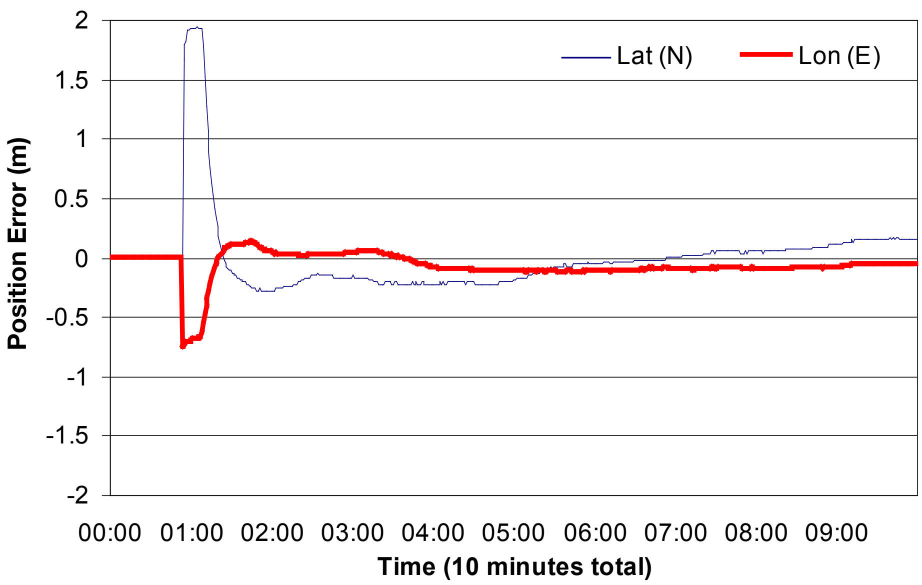
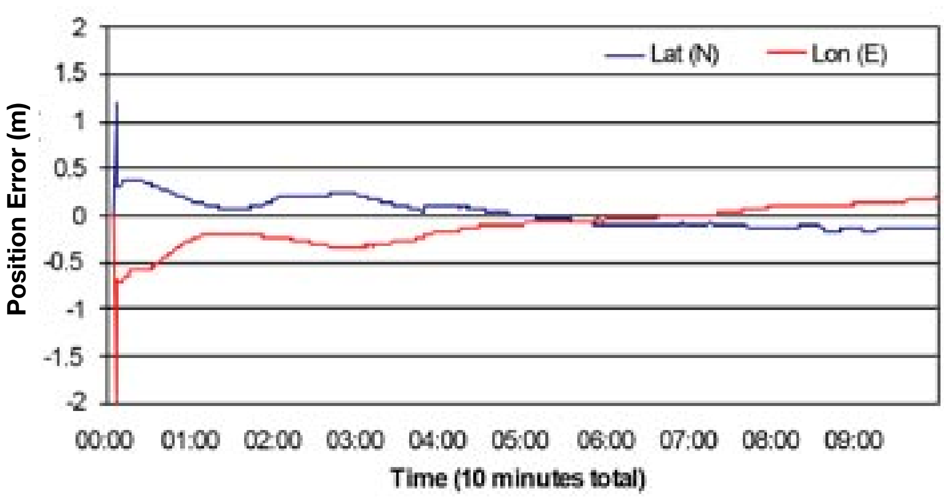


Figure 8: Reacquisition Time After Loss of GPS Lock



Conclusion

The introduction of the Crescent Receiver is the latest Hemisphere development that demonstrates our standard of innovation and excellence in providing cost-effective, high-performance GPS positioning solutions. Previous innovations have included our patented e-Dif and COAST technologies.

Our goal in developing our own ASIC technology was to provide the customer with the benefits of the freedom we now have in developing future products that are not restricted by the limitations of other chipsets. In addition we are able to provide higher update rates, improved raw measurement performance, larger memory space and processor capacity for more sophisticated applications and configuration settings.

Investing in the future of our company with our own developed technology will provide the basis of upcoming Hemisphere products with increased functionality that will add value and differentiate ourselves from other providers in the GPS market.

The Crescent OEM board marks the beginning of the new generation of products to be released. Ensuing releases of the Crescent product line will demonstrate the full capabilities of the receiver, and provide a wider variety of application possibilities with enhanced performance.

Appendix A: Specifications

GPS Sensor Specifications
Receiver Type: L1, C/A code, with carrier phase smoothing
Channels: 12-channel, parallel tracking (10-channel when tracking WAAS)
WAAS Tracking: 2-channel, parallel tracking
Update Rate: 20 Hz max
Horizontal Accuracy:
<1 m 95% confidence (DGPS)
< 2.5 m 95% confidence
<20 cm 95% confidence (L-Dif)
Cold Start: 60 s (no almanac or RTC)
Warm Start 1: 45 s (valid almanac, no RTC)
Warm Start 2: 35 s (valid almanac and RTC)
Hot Start: 20 s (valid almanac, RTC, and < 2 hours since last fix):
Reacquisition: < 1 s
Maximum Speed: 1607 kph (999 MPH)
Maximum Altitude: 18,288 m (60,000 ft)

Communications
Serial ports: 2 full duplex 3.3V CMOS
Baud Rates: 4800, 9600, 19200, 38400
Correction I/O Protocol: RTCM SC-104 (SBAS/Beacon), Proprietary format (L-Dif/RTK)
Data I/O Protocol: NMEA 0183, SLX binary
Timing Output: 1 PPS (HCMOS, active high, rising edge sync, 10 k, 10 pF load)
Event Marker Input: HCMOS, active low, falling edge sync,10 k, 10 pF load

Environmental
Operating Temperature: -30°C to +70°C
Storage Temperature: -40°C to +85°C
Humidity: 95% non-condensing
Shock: EP 455
Vibration: EP 455

Power
Input Voltage: 3.3 VDC +- 5%
Power Consumption: <1W nominal
Current Consumption: 300 mA nominal
Antenna Voltage Input: 15 VDC maximum
Antenna Short Circuit Protection: Yes
Antenna Gain Input Range: 10 to 40 dB
Antenna Input Impedance: 50

Mechanical
Dimensions: <71.1 mm L x <40.6 mm W x <12 mm H (<2.8″ L x <1.6″ W x <0.5″ H)
Weight: <20 g (<0.75 oz)
Status Indication: 4 surface-mount LED's indicating power, GPS lock, differential lock, and DGPS position
Power/Data Connector: 34-pin male header, 0.05″ pitch
Antenna Connector: MCX, female, straight (right angle available)

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