Pixhawk Compatible GNSS Receiver Comparison

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Prelude:

A GNSS navigation receiver isn't about giving your vehicle the ability to go from "Point A" to "Point B". It's about getting to the destination safely while dealing with interference from surroundings along the way in a stable fashion. How can you leverage the autonomous functionality of a complex vehicle and choose an economical, minimally sufficient navigation device? You can't. Not when your reputation depends on it.

There are several commonly known GNSS receivers that are compatible with the Pixhawk series, and Pixhawk based, autopilots. This document outlines some of the advertised/published capabilities of each receiver and compares this data with actual observations.

The primary goal of these findings is to compare manufacturer/reseller advertised capabilities versus actual, out-of-the-box results. While it is generally not good practice to use a GNSS receiver near structures, in real-world applications, structural or environmental interference of some type is likely to be encountered. Therefore, data was collected both in an "open" and clear baseline scenario, then under extreme multi-path interference conditions while the GNSS receivers were placed directly next to a commercial building. The data represented in this document depicts the receiver reported values given each situation.

All information presented in this document is current as of April 2018.

Disclosures:

Titan Elite, Inc. is currently a distributor and manufacturer for Zubax Robotics products.

Images, screen shots, device specifications, manufacturer and designer references discussed hereinafter have been gathered from public domain resources including published website pages and device documentation. Titan Elite, Inc. does not take ownership or credit for any logos, branding collateral, copyright material, or website content from 3D Robotics, Mayan Robotics LLC, Drotek Electronics, or Hex Technology Limited.

Executive Summary

This document outlines some of the performance differences between well-known Pixhawk autopilot compatible GNSS receivers. The Pixhawk autopilot provides autonomous functionality to unmanned vehicle systems and incorporates GNSS position estimate data in an attempt to provide stable position accuracy. GNSS receivers including the 3D Robotics GPS, Mayan Robotics NEO-M8N, Drotek NEO-M8T XL, Hex Here GNSS, and Zubax Robotics GNSS 2 have been compared.

The primary purpose of this review was to compare advertised versus actual capabilities. The secondary purpose of the test was to define the average and maximum (or minimum) observed capabilities of each receiver in a given time period.

All receivers were purchased as brand new equipment. All receivers were opened and tested in their "out of the box configuration" in a bench setup test environment. Test data was collected using the uBlox U-Center desktop program. The first test was performed for baseline testing in an "open sky", relatively obstruction free environment. The second test was performed in an "extreme" situation whereby the GNSS receivers were placed within 1 meter of a commercial building.

The results reported that the majority of GNSS receivers observed fewer concurrent satellite constellations than advertised. The Zubax Robotics GNSS 2 and the 3D Robotics GPS receivers accurately utilized those constellations which were advertised. The Mayan Robotics, Drotek and Hex GNSS receivers did not demonstrate the ability to utilize all of the constellations advertised.

The results indicated that the Zubax Robotics GNSS 2 was able to both track and utilize the highest number of individual satellites. The Mayan Robotics and 3D Robotics receivers demonstrated the lowest number of individual satellites tracked and utilized.

No results from the first two reports can be observed regarding estimated horizontal accuracy reported by each receiver since the majority of devices did not report this data in the uBlox U-Center program by their default, out-of-the-box configuration. During the first and second tests, the estimated horizontal accuracy was only reported by the Zubax GNSS 2 while all other receivers did not publish this data.

A third and fourth bench test were performed after configuring each device to report its estimated horizontal accuracy. A minimum (best) and average value was reported. The Zubax GNSS 2 reported the most favorable values in both tests while the 3D Robotics and Mayan Robotics receivers reported the least favorable results, respectively.

GNSS Receiver Performance Review

April 2018

1. **Purpose.** The purpose of this paper is to compare the actual versus advertised performance of several popular GNSS receivers designed for use with the Pixhawk series autopilot. The Pixhawk series autopilots are an open-source, community driven device which enables autonomous mission capabilities of various vehicle types. The GNSS receiver is arguably one of the most mission critical components of the autonomous system as the device is largely responsible for the vehicle's ability to travel from one location to another, or maintain position as commanded by the autopilot. A GNSS receiver should be reliable and provide accurate position estimation data because it is the primary guidance sensor that the autopilot relies on for autonomous or semi-autonomous functionality.

The devices reviewed in this guide have been selected due to their familiarity in the Pixhawk community. These GNSS receivers include:

Device	Manufacturer / Designer	Model
1	3D Robotics	GPS + Compass
2	mRo (Mayan Robotics)	mRo GPS uBlox Neo-M8N
3	Drotek	uBlox NEO-M8T GPS + HMC5983 Compass (XL)
4	Hex / Proficnc	HERE GNSS
5	Zubax Robotics	Zubax GNSS 2

Table 1: GNSS receivers tested during this review.

2. **Test Environment & Parameters.**

A. The following test results were observed in the following environment conditions:
   a. Sky condition: Clear and open skies
   b. Temperature: 47 degrees F (8.3 degrees C)
   c. Humidity: 44%
   d. Dew point: 26 degrees F (-3.3 degrees C)

B. Results were based on observations recorded at the end of approximately a 5 minute period.

C. Observations and testing was performed first, approximately 35 feet (10.6m) from a commercial building. Next, observations and testing were performed approximately 3 feet (0.9m) from a commercial building. The exterior of the building and visible features are constructed primarily of concrete, steel and aluminum.

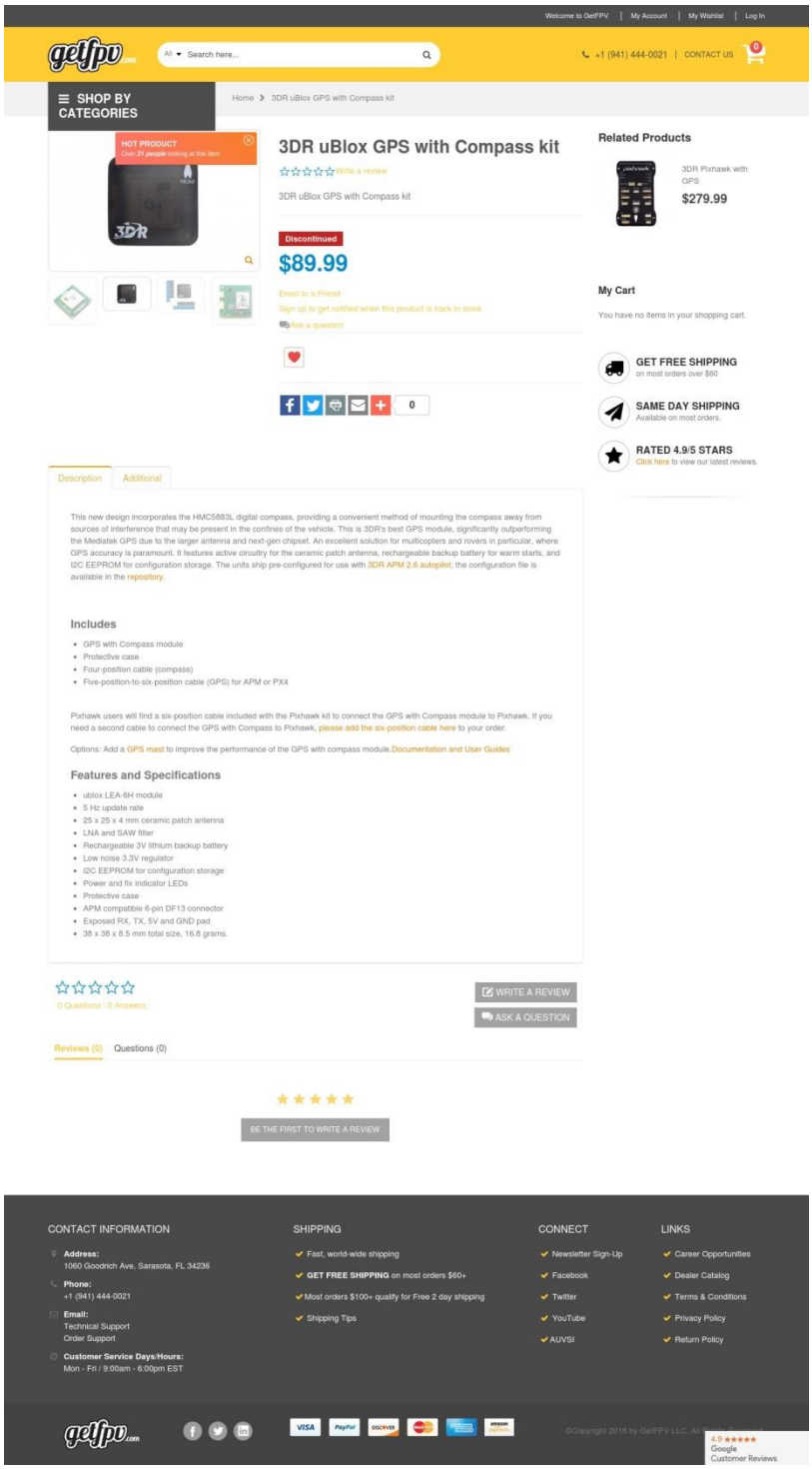
Photo: Bench-test setup for initial test, approximately 35 feet (10.6m) from the nearest structure

Photo: Bench-test setup for second test, approximately 3 feet (0.9m) from the nearest structure

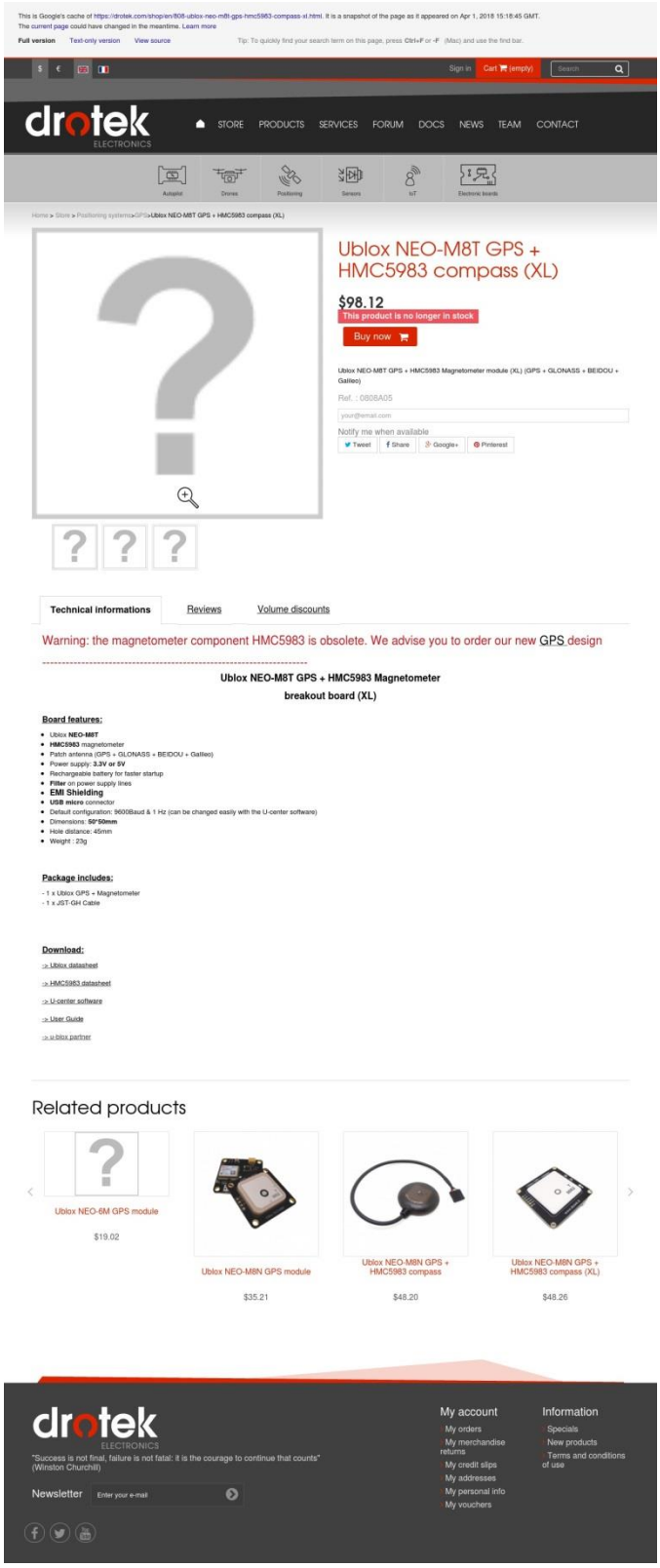
3. Device Reference Information.

Reference product listing page screen shots (full page):

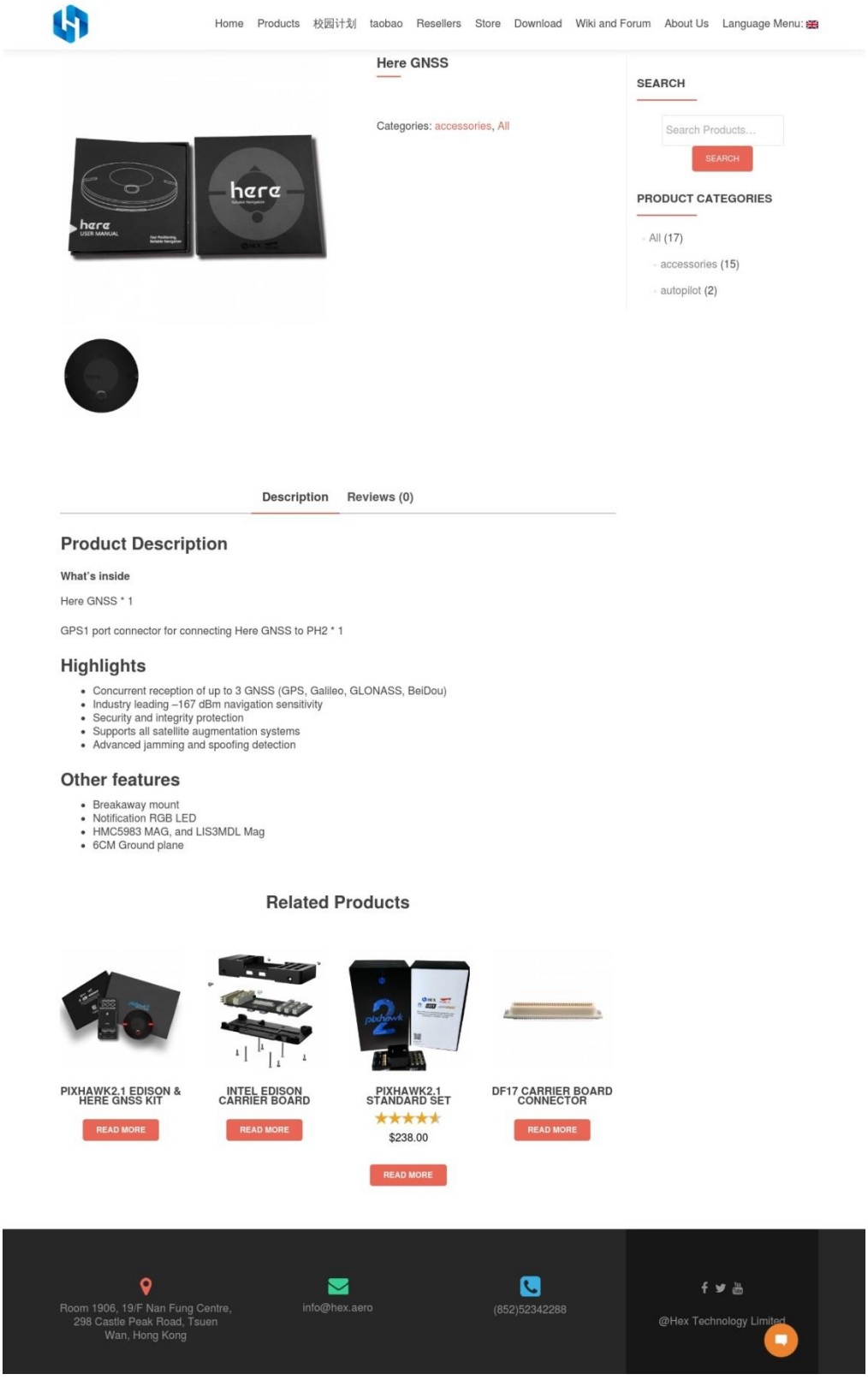
3D Robotics GPS



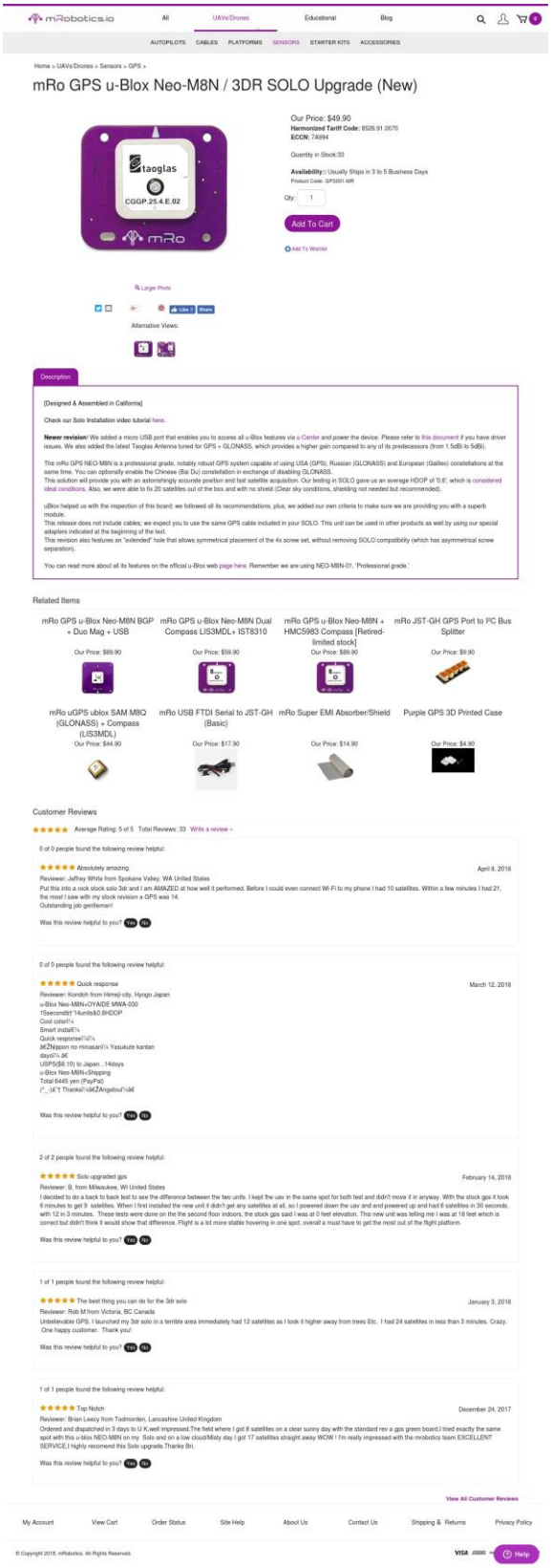
Drotek uBlox NEO-M8T GPS (XL)



Here GNSS


Home Products 校园计划 taobao Resellers Store Download Wiki and Forum About Us Language Menu:
Here GNSS
Categories: accessories, All
SEARCH
Search Products...
SEARCH
PRODUCT CATEGORIES
All (17)
accessories (15)
autopilot (2)
Description Reviews (0)
Product Description
What's inside
Here GNSS * 1
GPS1 port connector for connecting Here GNSS to PH2 * 1
Highlights
Concurrent reception of up to 3 GNSS (GPS, Galileo, GLONASS, BeiDou)
Industry leading –167 dBm navigation sensitivity
Security and integrity protection
Supports all satellite augmentation systems
Advanced jamming and spoofing detection
Other features
Breakaway mount
Notification RGB LED
HMC5983 MAG, and LIS3MDL Mag
6CM Ground plane
Related Products
PIXHAWK2.1 EDISON & HERE GNSS KIT
READ MORE
INTEL EDISON CARRIER BOARD
READ MORE
PIXHAWK2.1 STANDARD SET
$238.00
READ MORE
DF17 CARRIER BOARD CONNECTOR
READ MORE
Room 1906, 19/F Nan Fung Centre, 298 Castle Peak Road, Tsuen Wan, Hong Kong
info@hex.aero
(852)52342288
@Hex Technology Limited

mRo GPS uBlox NEO-M8N



Zubax GNSS 2


Zubax GNSS 2 Receiver, GPS + GLONASS + Galileo with Ublox MAX M8 (M8Q) Engine
$129.00
Available Options
Zubax GNSS 2 Basic Configuration Guide for Pixhawk Connectivity
Both quadcopters landed manually to complete first test flight
...choose the Zubax GNSS 2
Related Products

Reference product listing page screen shots (partial page):

3D Robotics GPS

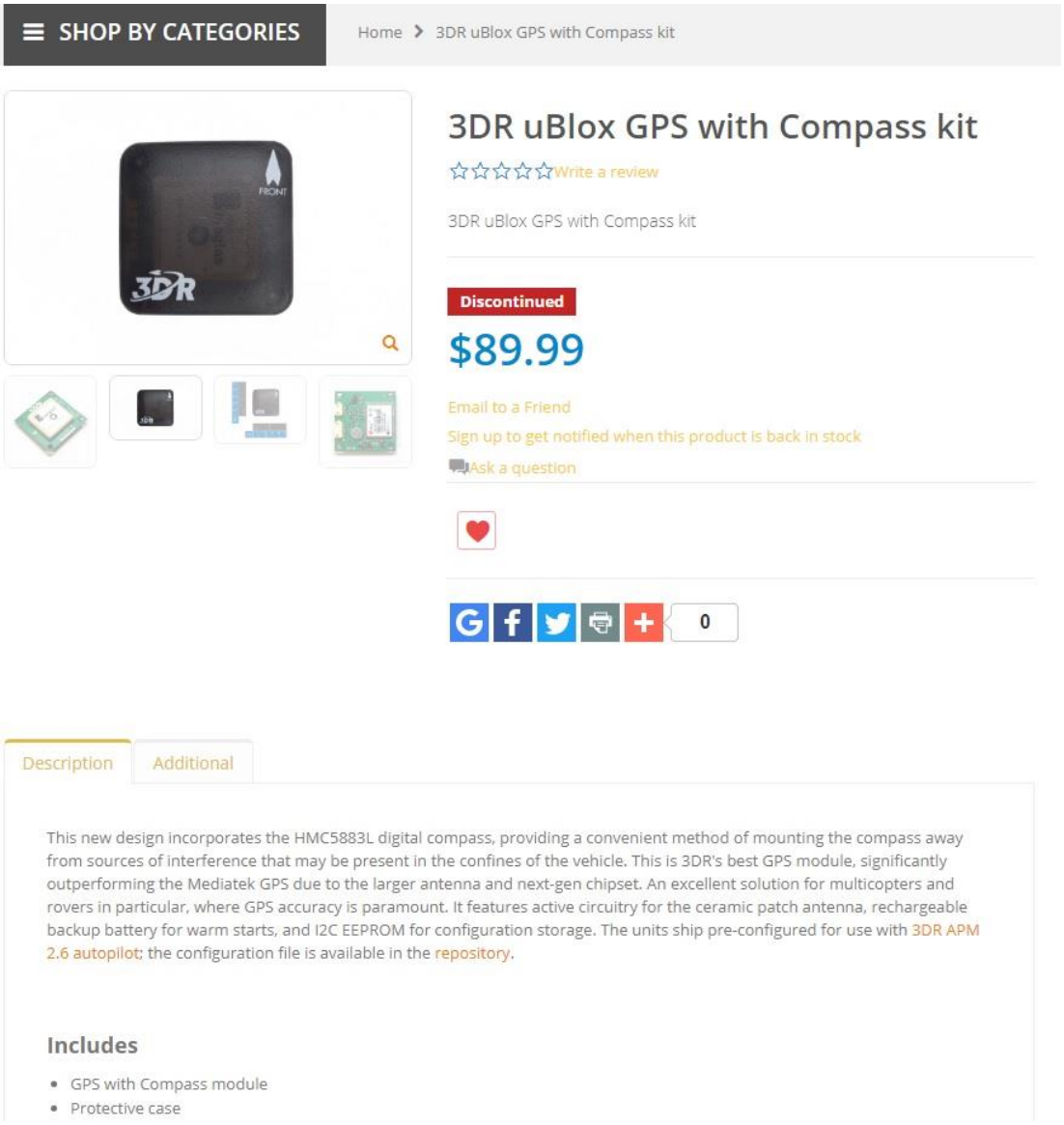


Image reference: https://getfpv.com

Drotek uBlox NEO-M8T GPS (XL)

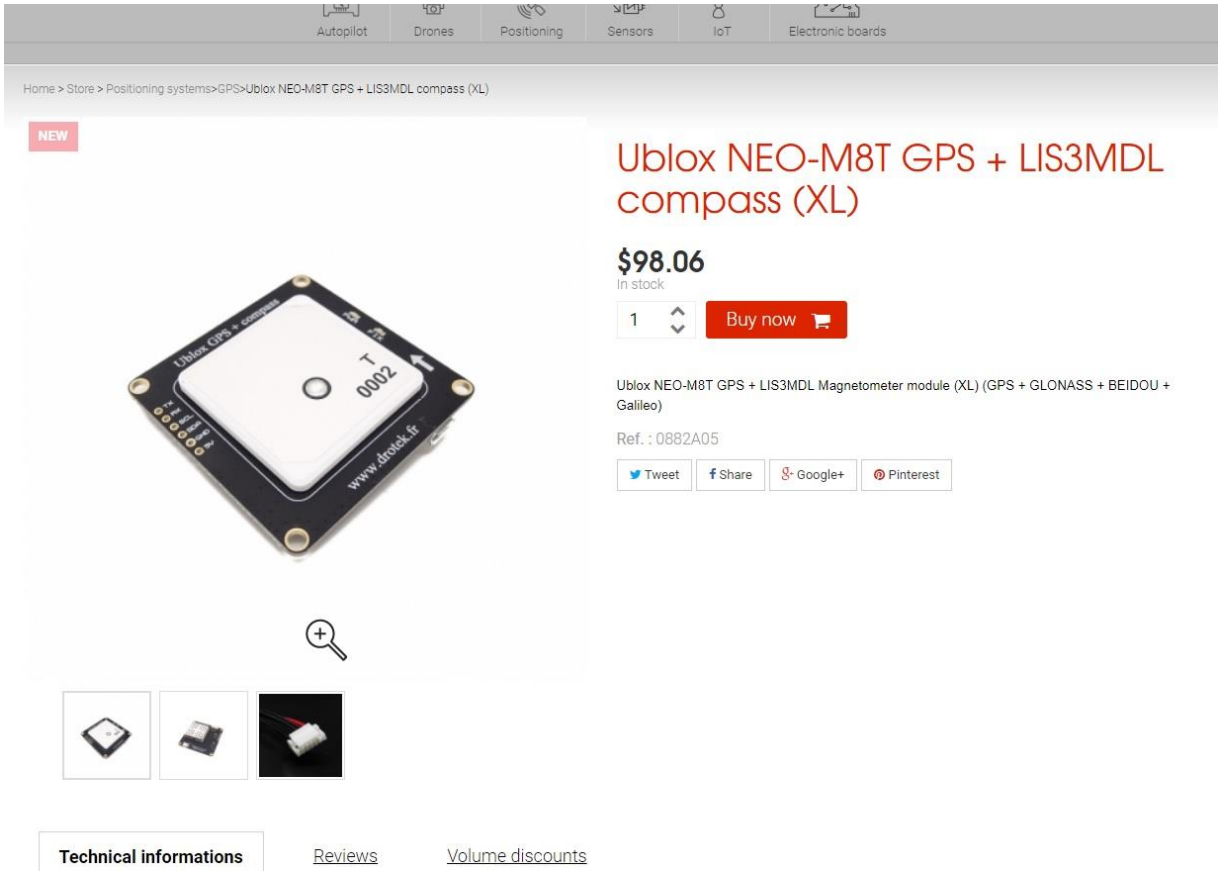


Image reference: https://drotek.com

Here GNSS

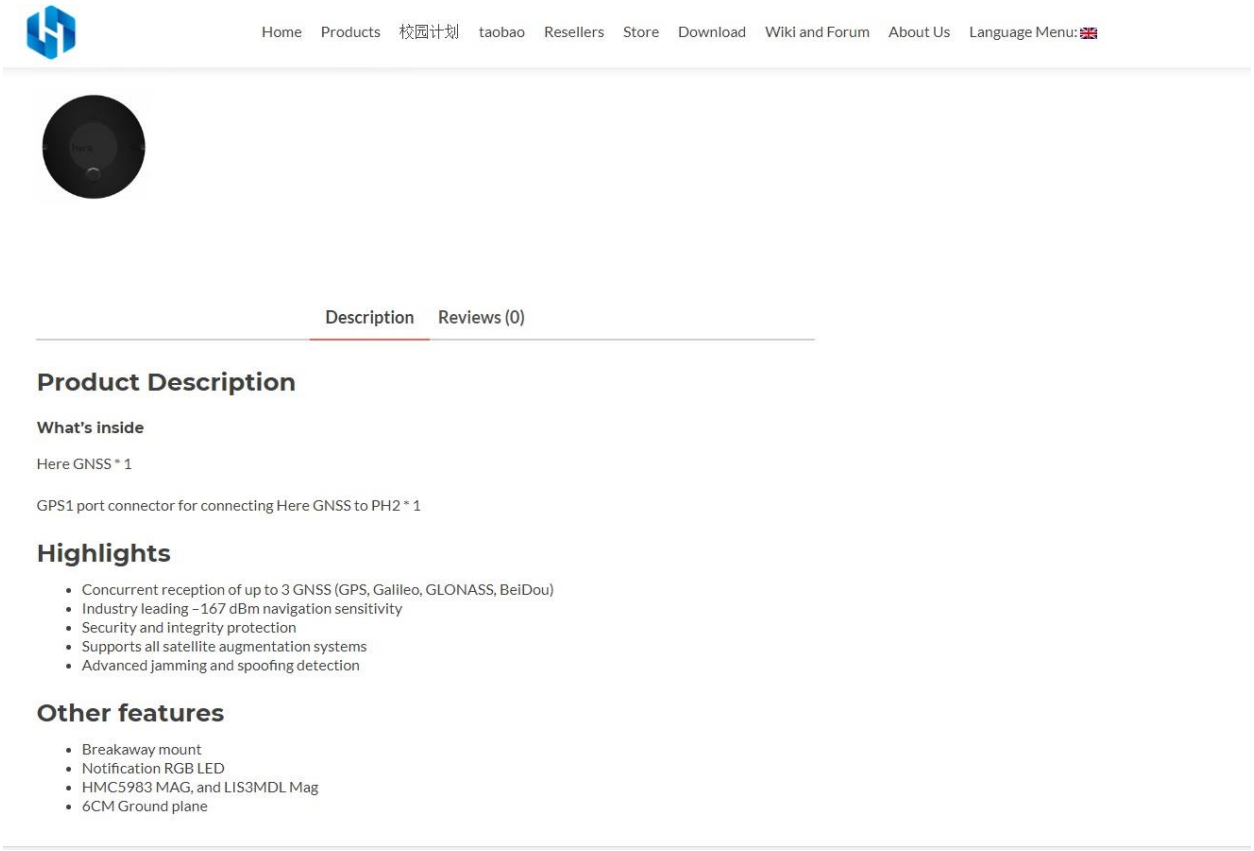


Image reference: http://hex.aero

mRo GPS uBlox NEO-M8N

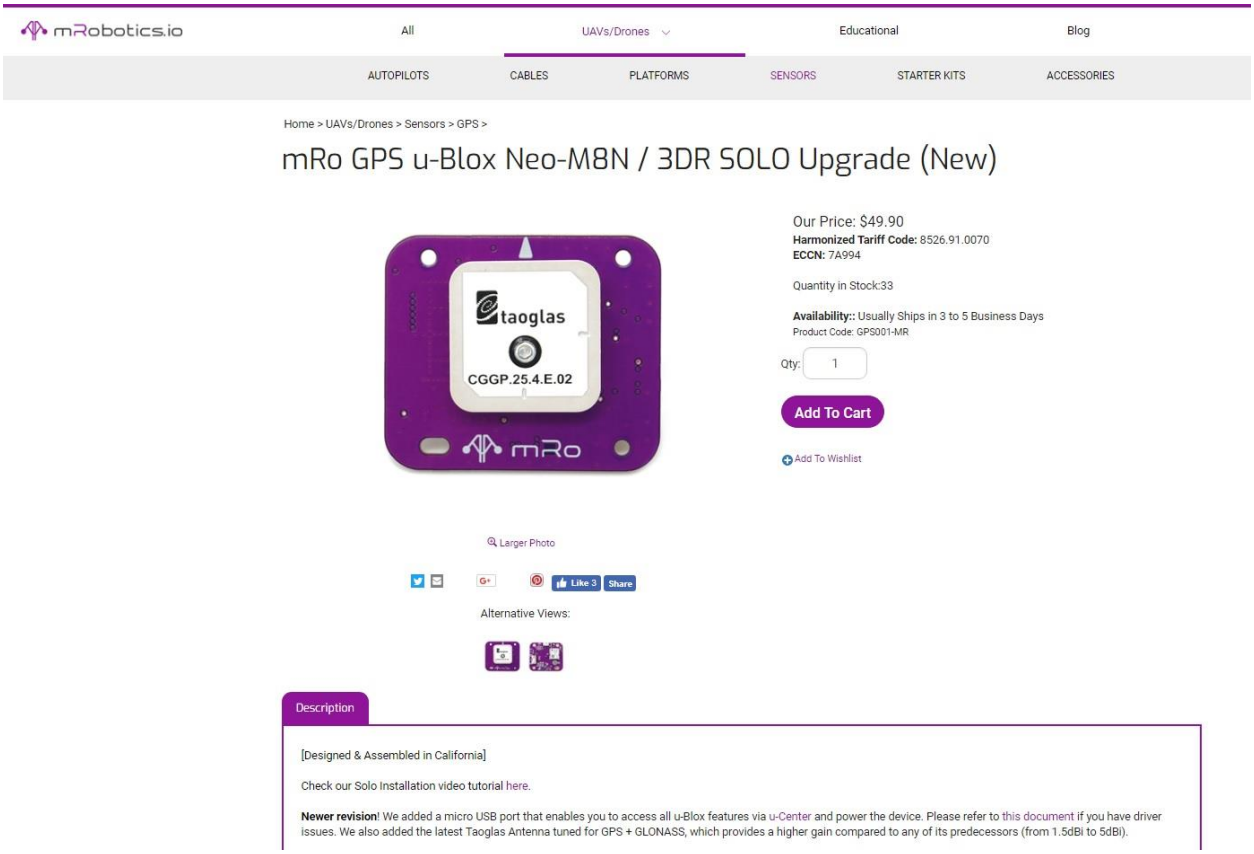


Image reference: https://store.mrobotics.io

Zubax GNSS 2

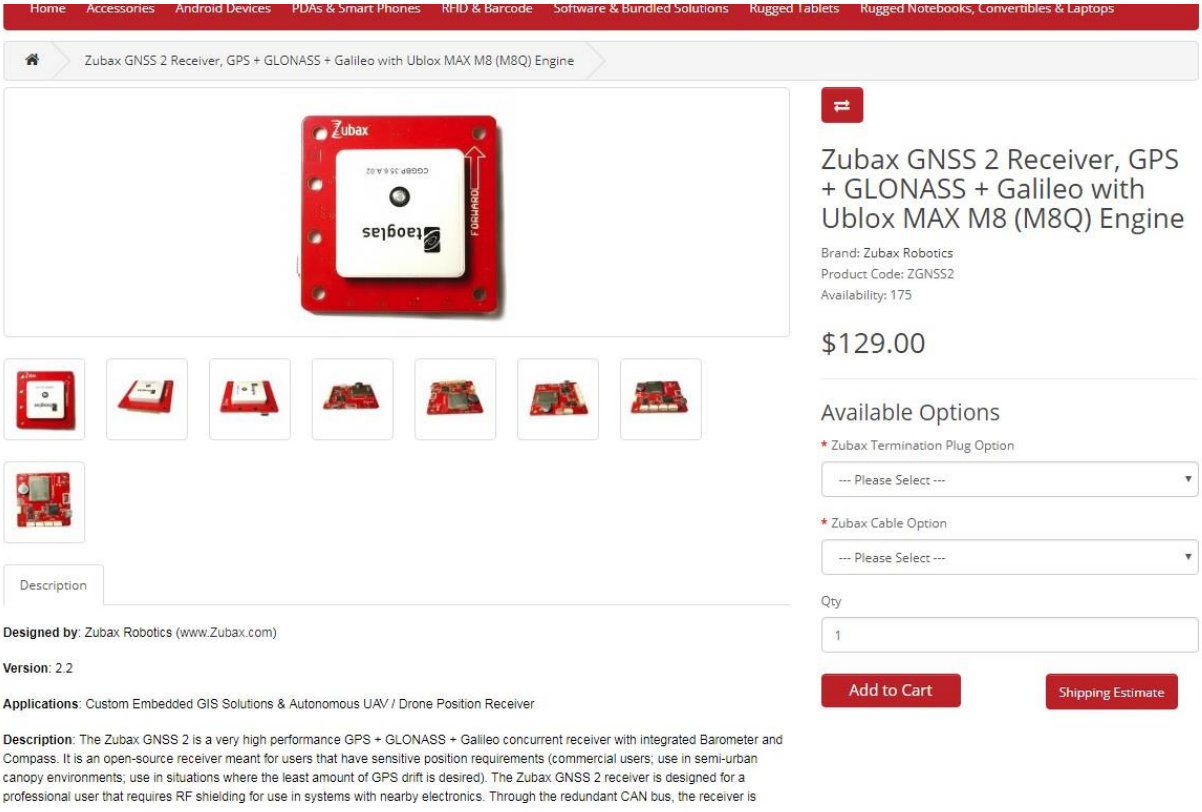


Image reference: https://shop.titaneliteinc.com

4. Results.

Results were recorded using the uBlox U-Center program (v8.27).
Link to uBlox U-Center: https://www.u-blox.com/en/product/u-center-windows

A. Advertised navigation satellite constellations available (as per the manufacturer / designer's website) versus actual concurrent satellite constellations used.

Device	Manufacturer / Designer	Model	Concurrent Constellations available (advertised)	Concurrent Constellations used (actual)
1	3D Robotics	3DR GPS + Compass	GPS	✔ GPS
2	mRo (Mayan Robotics)	mRo GPS uBlox Neo-M8N	GPS Galileo GLONASS	✔ GPS X X
3	Drotek	uBlox NEO-M8T GPS + HMC5983 Compass (XL)	GPS Galileo GLONASS BeiDou	✔ GPS X ✔ GLONASS X
4	Hex / Proficnc	HERE GNSS	GPS Galileo GLONASS BeiDou	✔ GPS X ✔ GLONASS X
5	Zubax Robotics	Zubax GNSS 2	GPS Galileo GLONASS	✔ GPS ✔ Galileo ✔ GLONASS

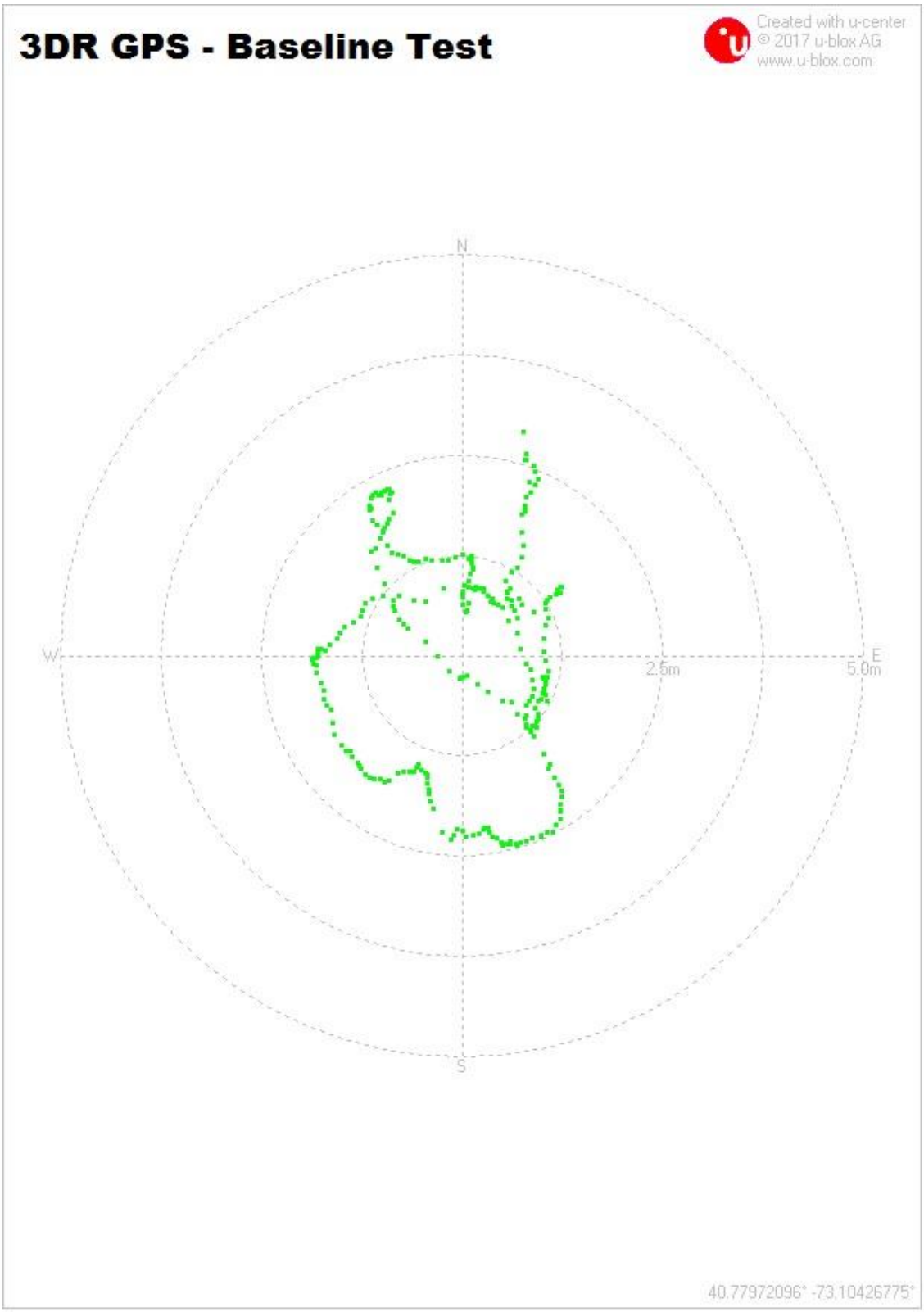
Table 2: Advertised versus actual constellations utilized

B. Satellite and position data – First Test, 35 feet (10.6m) from structure

	mRo GPS uBlox Neo-M8N	**Zubax GNSS 2**	**Drotek uBlox NEO-M8T GPS + HMC5983 compass (XL)**	**HERE GNSS**	**3DR GPS**
Maximum number of satellites in view (SVs tracked max.)	20	74	20	24	15
Actual satellite constellations observed during test	GPS	GPS GLONASS Galileo	GPS GLONASS	GPS GLONASS	GPS
Average Horizontal Position Accuracy Reported by Receiver (PACC H)	None reported	0.516 Meters	None reported	None reported	None reported
Number of satellites used for navigation AVERAGE (SVs used Avg.)	6	13	9	9	8
Number of satellites used for navigation MAXIMUM (SVs used Max.)	7	16	10	13	10
Max. observed horizontal deviation from center (estimated based on deviation graph)	3.5 meters	2.5 meters	3.8 meters	3.7 meters	2.8 meters

Table 3: Satellite and perceived position data – First Test

1. Deviation Graphs - First Test: 35 feet (10.6m) from structure
   Note: The outer circle represents a distance of 5 meters from the "center point" of the estimated position.


3DR GPS - Baseline Test
Created with u-center
© 2017 u-blox AG
www.u-blox.com
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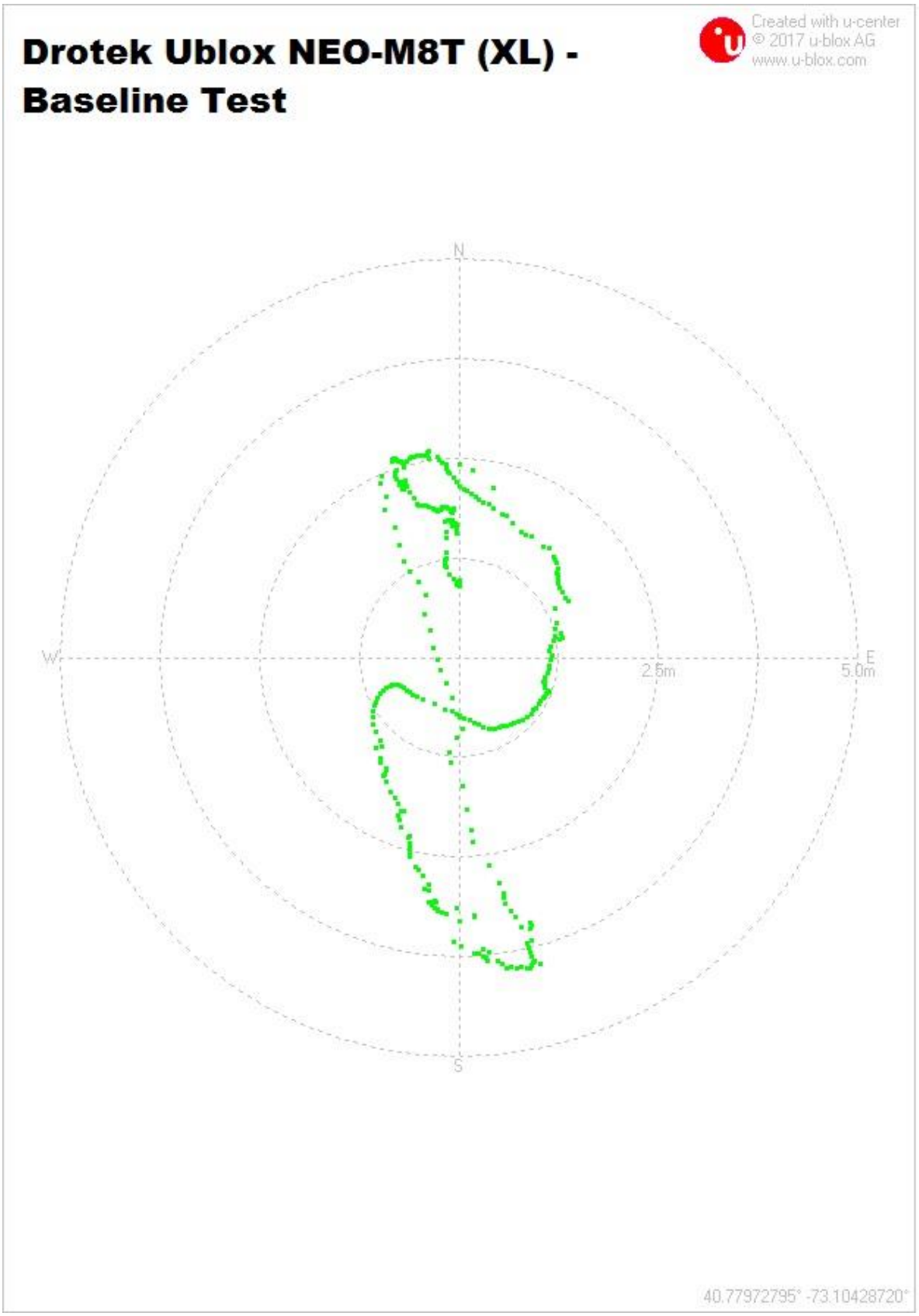
Drotek Ublox NEO-M8T (XL) -
Baseline Test
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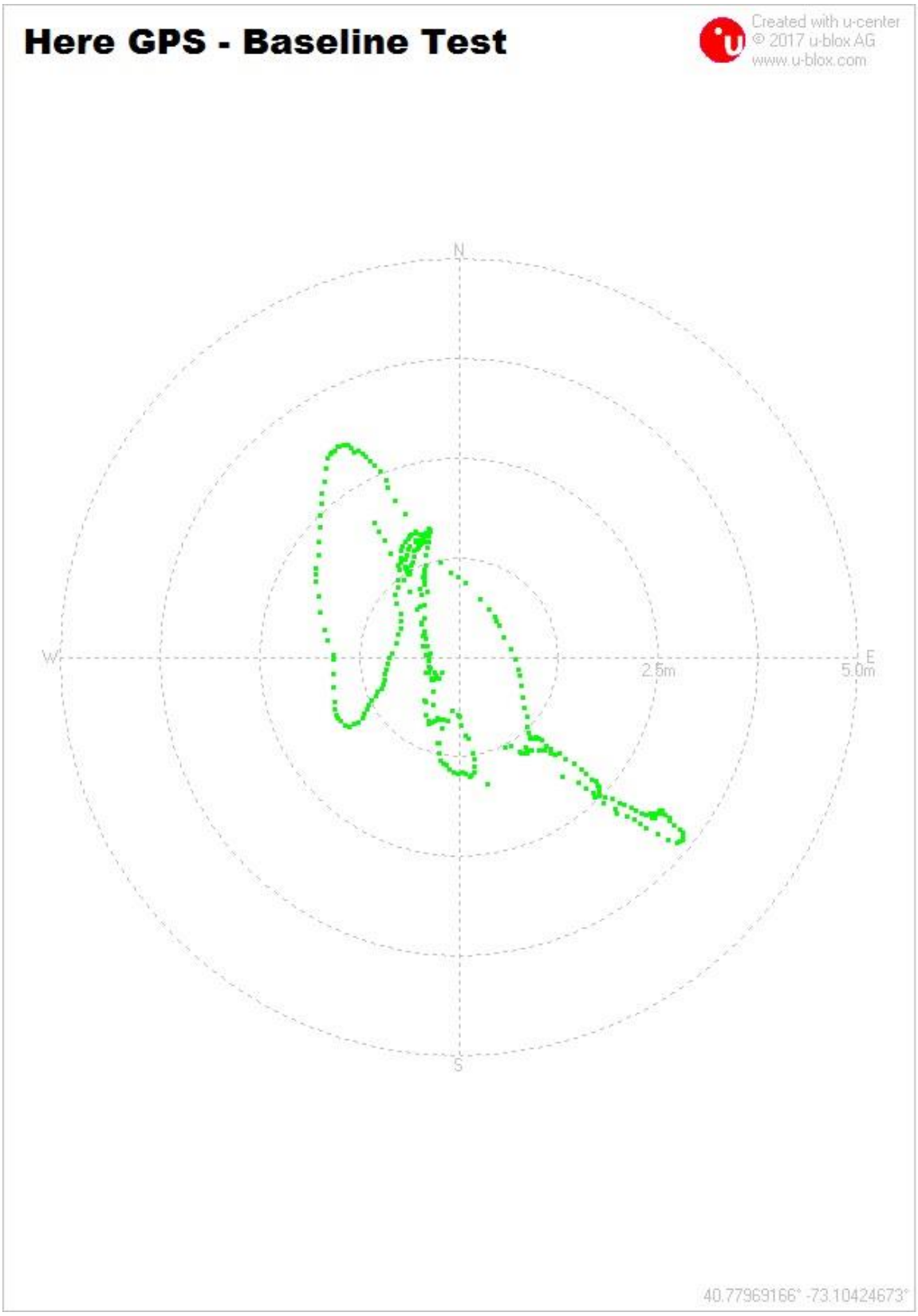
Here GPS - Baseline Test
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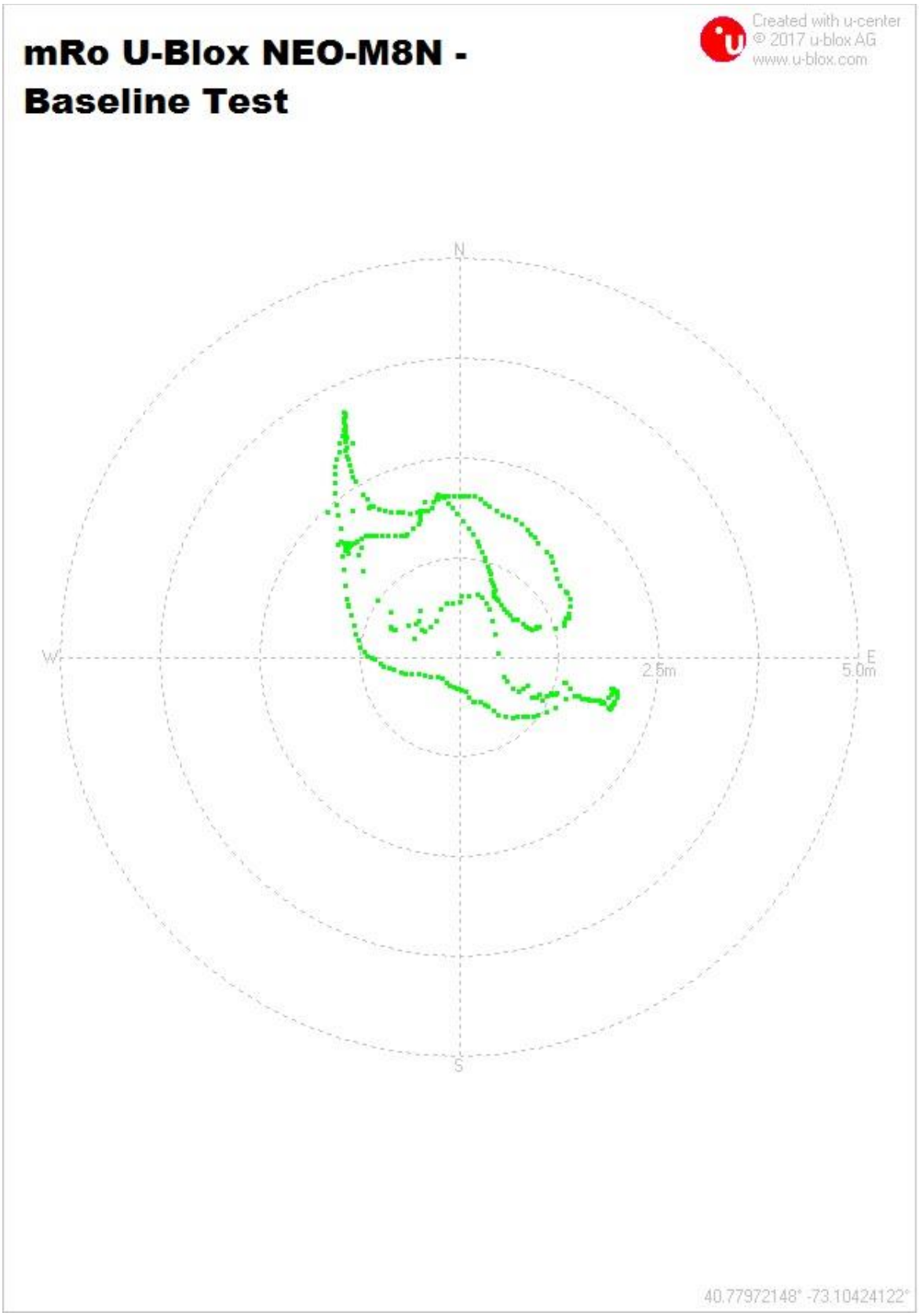
mRo U-Blox NEO-M8N -
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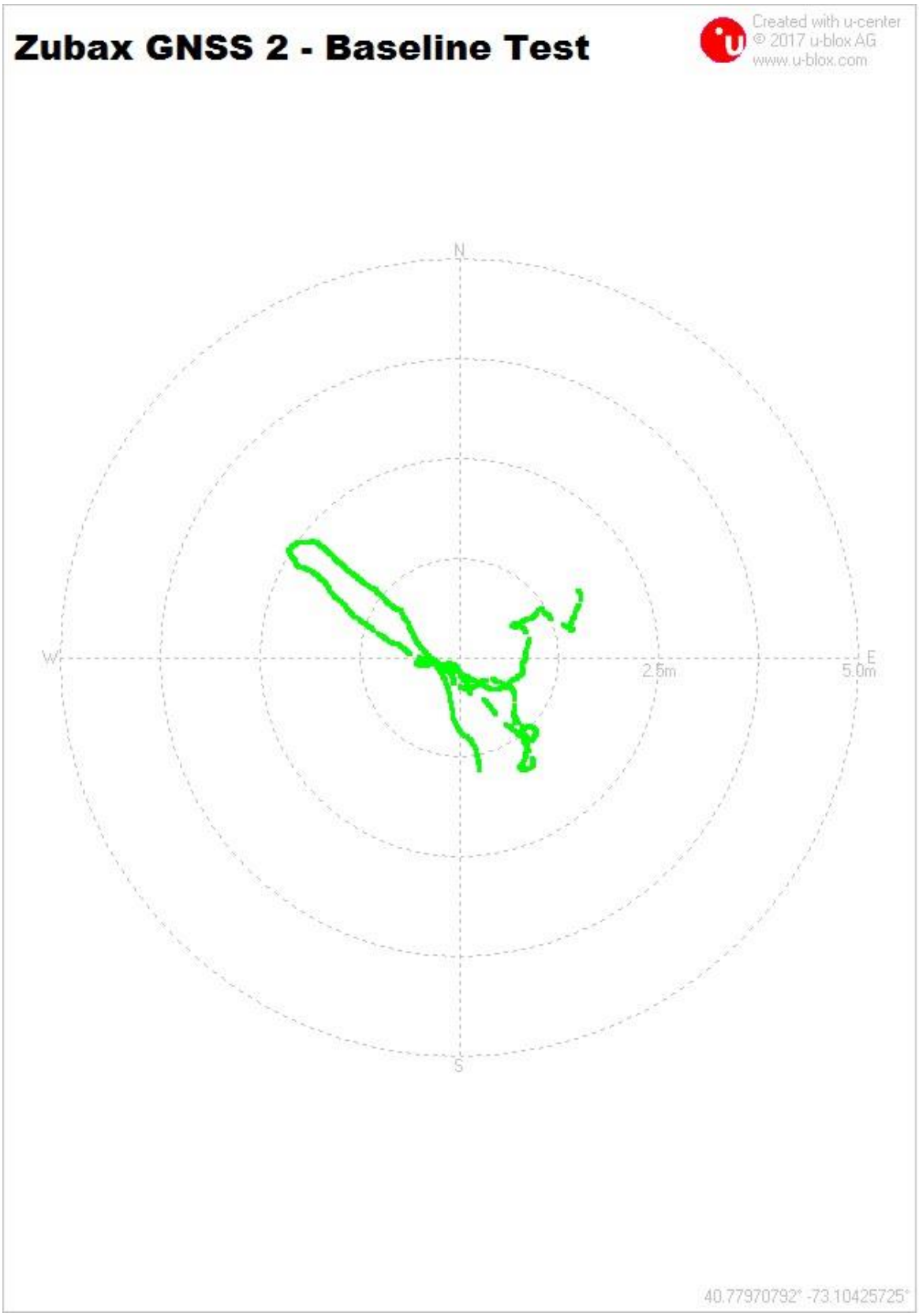
Zubax GNSS 2 - Baseline Test
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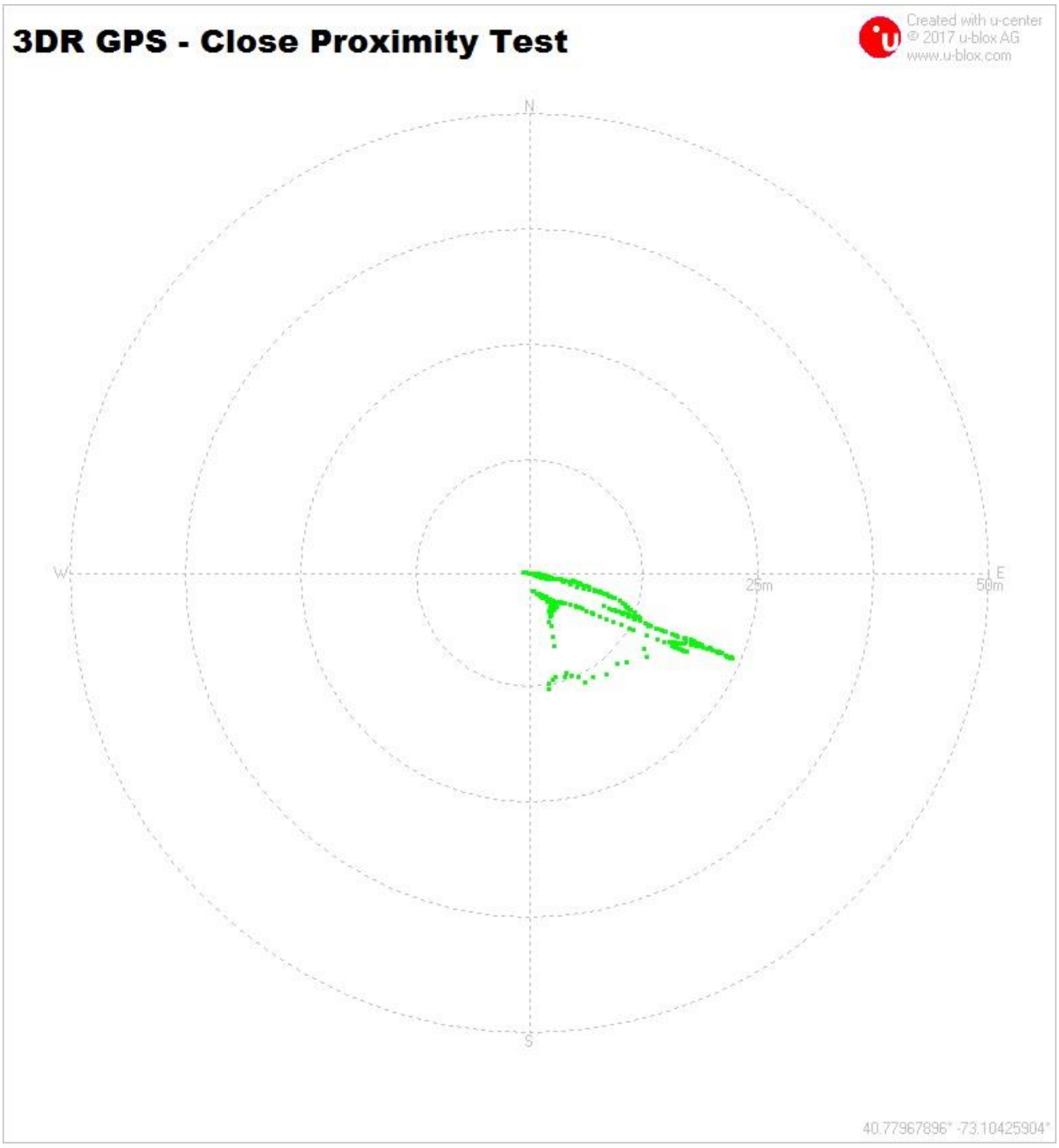
C. Satellite and position data – Second Test, 3 feet (0.9m) from structure

	mRo GPS uBlox Neo-M8N	**Zubax GNSS 2**	**Drotek uBlox NEO-M8T GPS + HMC5983 compass (XL)**	**HERE GNSS**	**3DR GPS**
Maximum number of satellites in view (SVs tracked max.)	10	72	17	23	12
Actual satellite constellations observed during test	GPS	GPS GLONASS Galileo	GPS GLONASS	GPS GLONASS	GPS
Average Horizontal Position Accuracy Reported by Receiver (PACC H)	None reported	1.002 Meters	None reported	None reported	None reported
Number of satellites used for navigation AVERAGE (SVs used Avg.)	6	14	9	11	8
Number of satellites used for navigation MAXIMUM (SVs used Max.)	7	16	11	14	16
Max. observed horizontal deviation from center (estimated based on deviation graph)	31 meters	33 meters	35 meters	31 meters	24 meters

Table 4: Satellite and perceived position data – Second Test

1. Deviation Graphs - Second Test: 3 feet (0.9m) from structure
   Note: The outer circle represents a distance of 50 meters from the "center point" of the estimated position.


3DR GPS - Close Proximity Test
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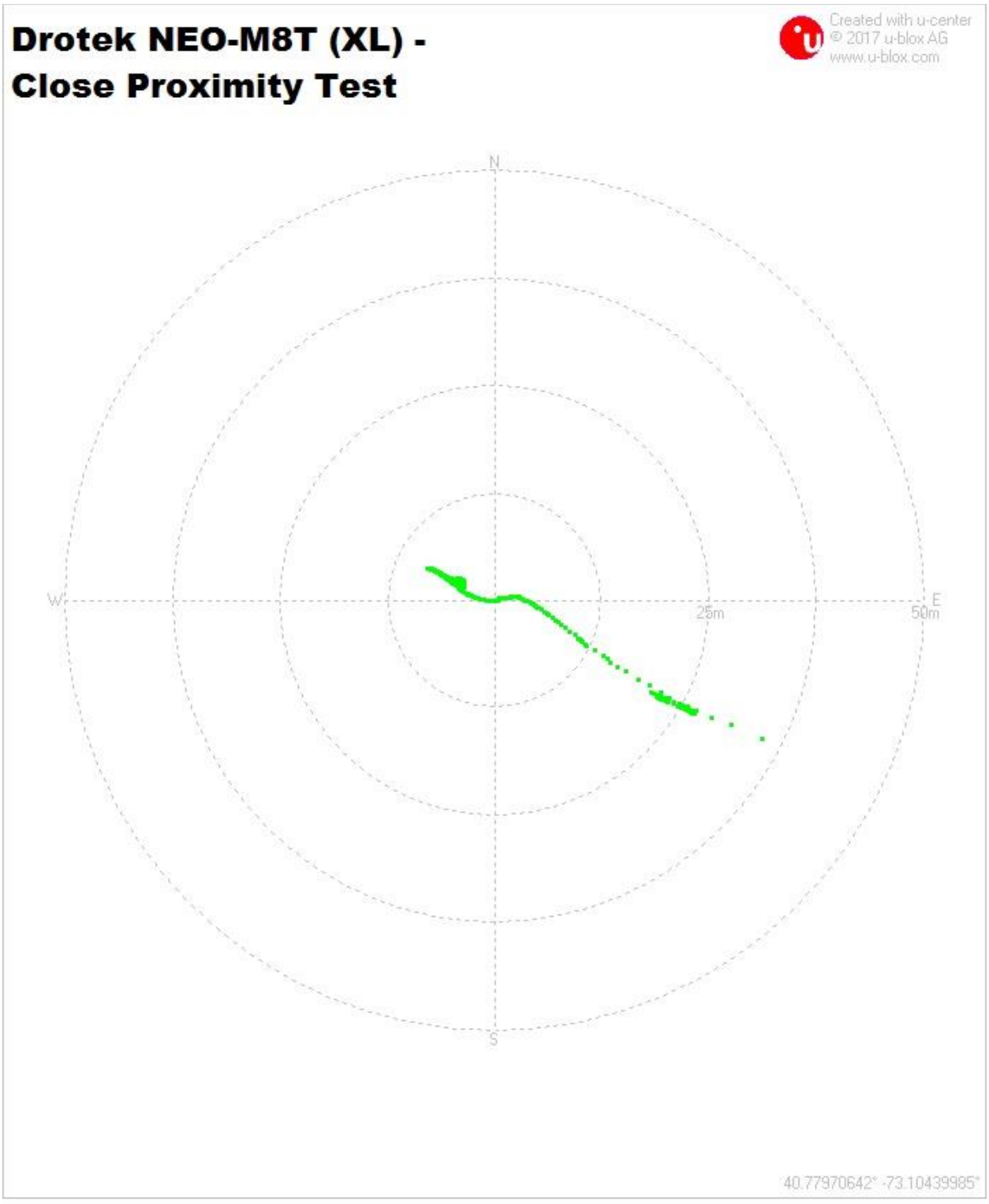
Drotek NEO-M8T (XL) -
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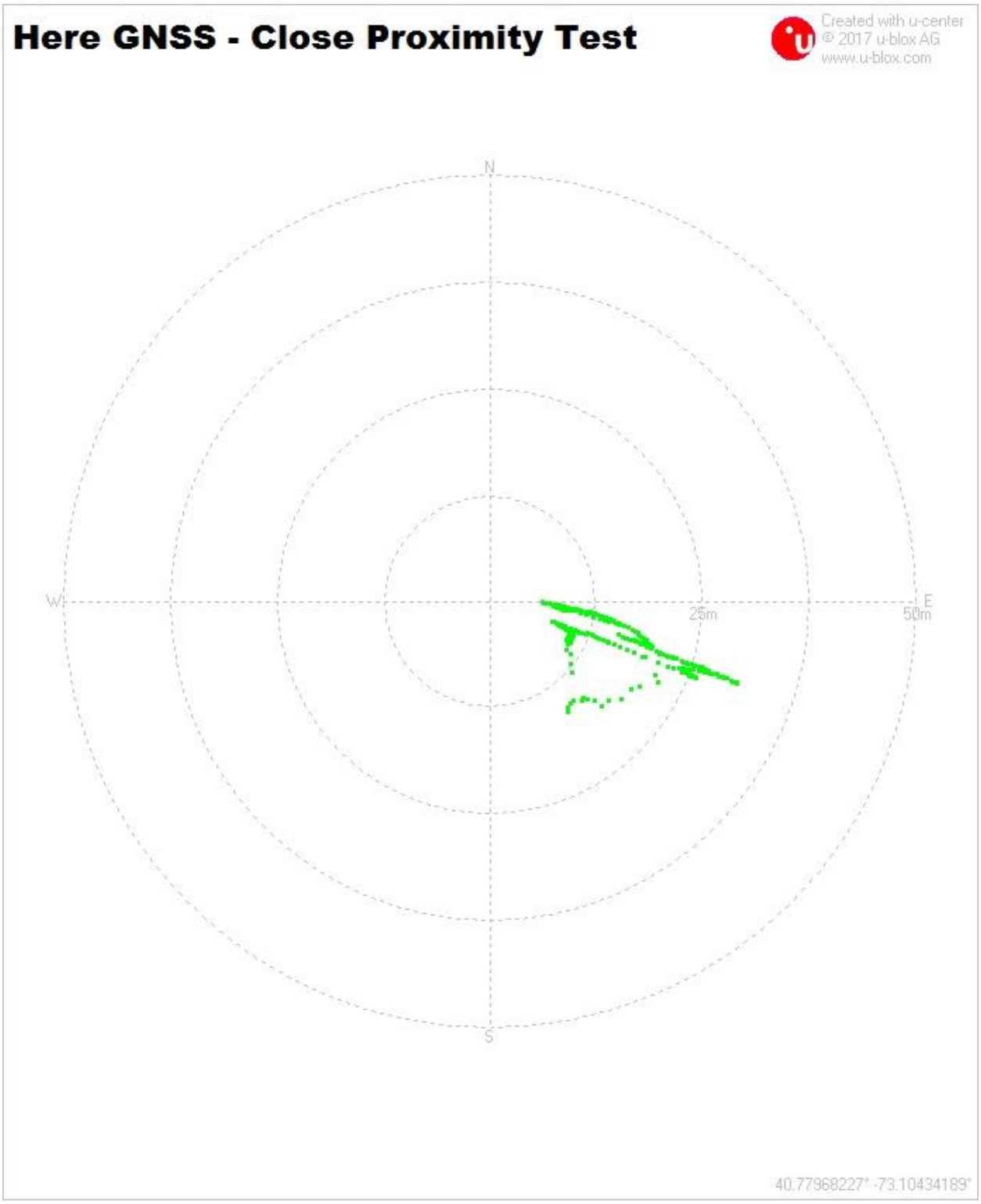
Here GNSS - Close Proximity Test
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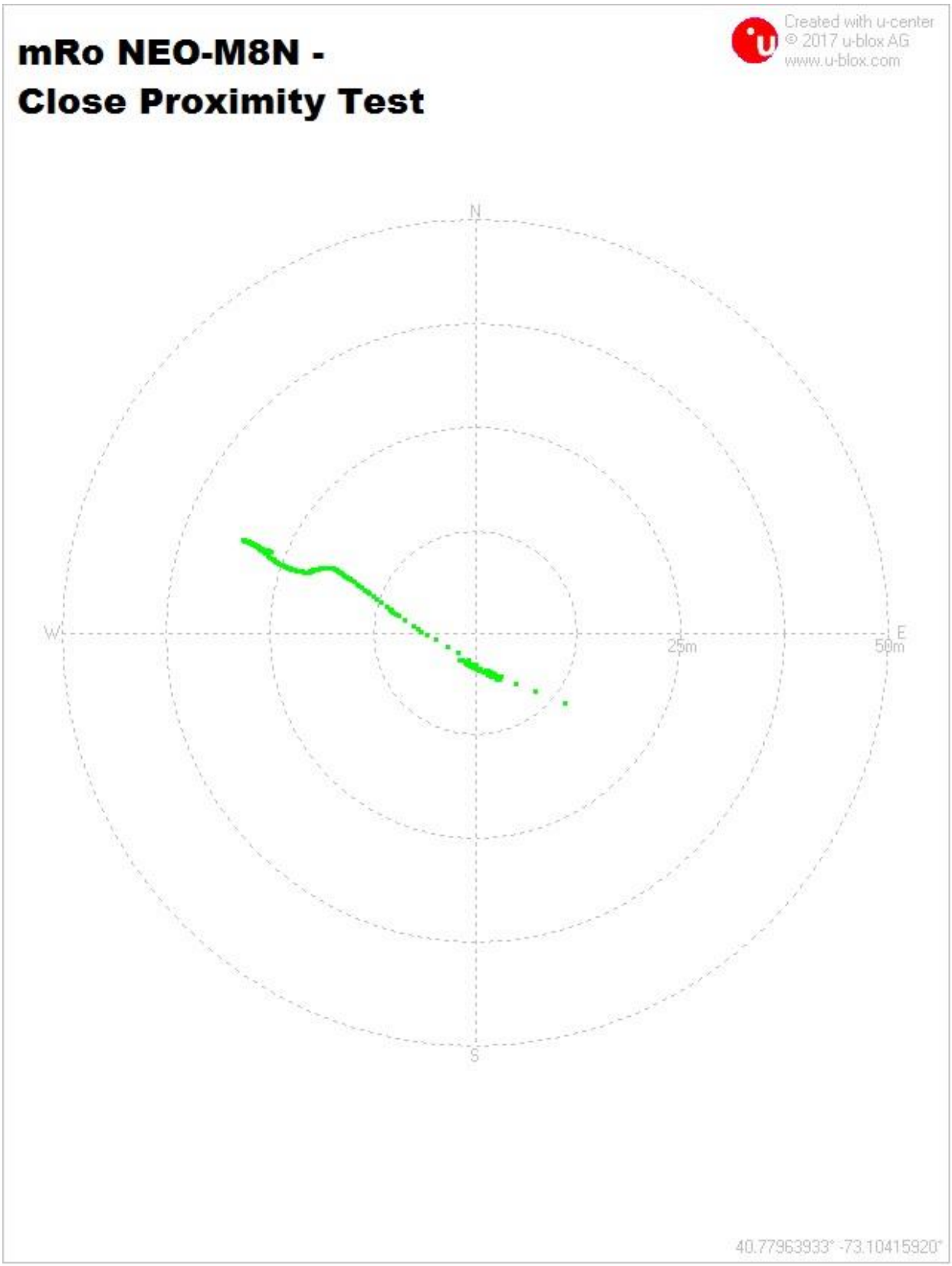
mRo NEO-M8N -
Close Proximity Test
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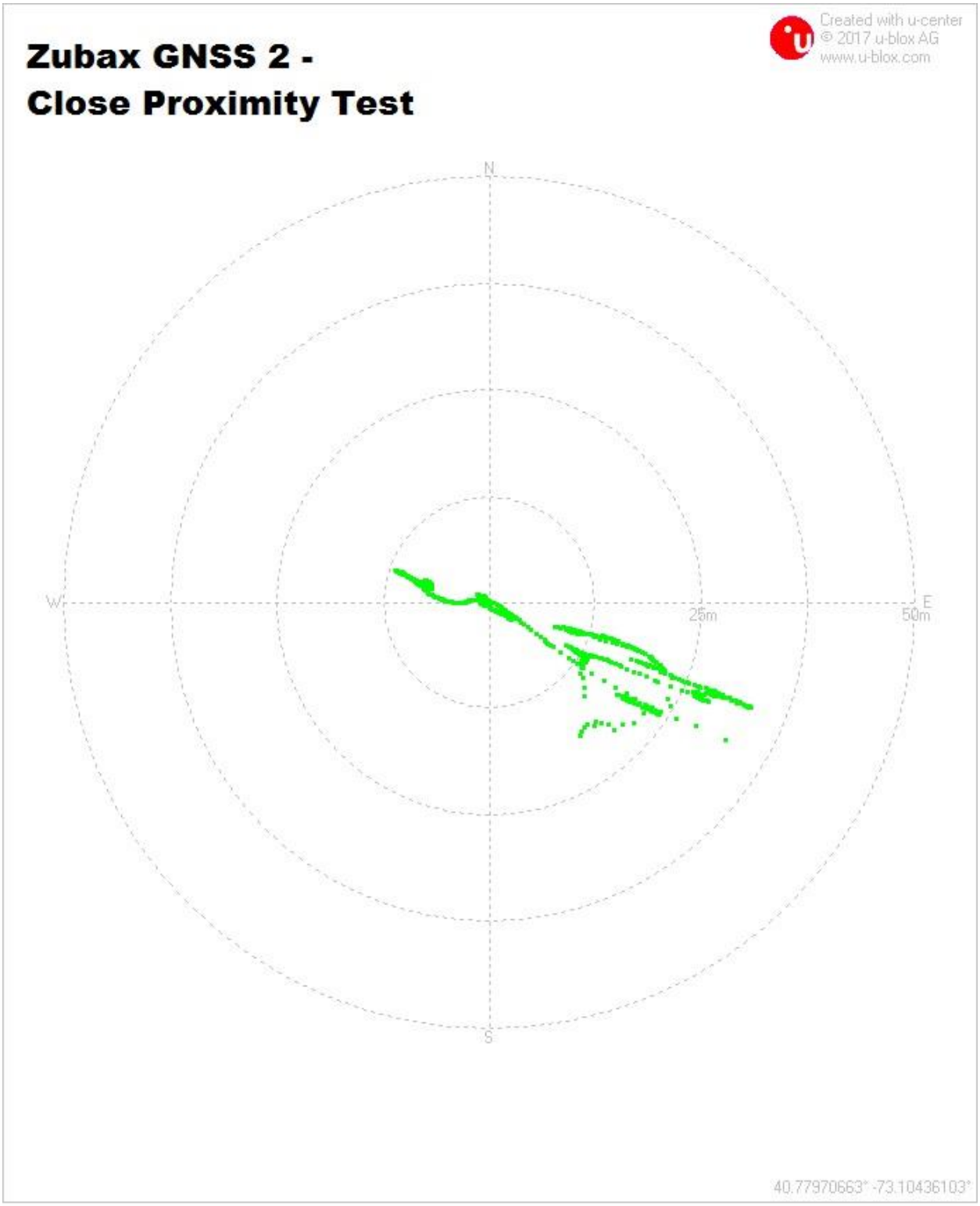
Zubax GNSS 2 -
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5. **Log files.** The log files from each test period may be downloaded and opened using the uBlox U-Center program.

Device	Manufacturer / Designer	Model	Log File Download Link (First Test)	Log File Download Link (Second Test)
1	3D Robotics	3DR GPS + Compass	http://titaneliteinc.com/share/public/c70e43	http://titaneliteinc.com/share/public/3e6073
2	mRo (Mayan Robotics)	mRo GPS uBlox Neo-M8N	http://titaneliteinc.com/share/public/13e81c	http://titaneliteinc.com/share/public/fa94fe
3	Drotek	uBlox NEO-M8T GPS + HMC5983 Compass (XL)	http://titaneliteinc.com/share/public/543c8e	http://titaneliteinc.com/share/public/f6e5b1
4	Hex / Proficnc	HERE GNSS	http://titaneliteinc.com/share/public/0be50d	http://titaneliteinc.com/share/public/e82dfb
5	Zubax Robotics	Zubax GNSS 2	http://titaneliteinc.com/share/public/a0da4b	http://titaneliteinc.com/share/public/9a04d1

Table 5: uBlox U-Center Log Files

6. **Publicly advertised information.** The following specifications are reported based upon data found on the designer or manufacturer's website.

	3DR GPS	mRo GPS uBlox Neo-M8N	Drotek uBlox NEO-M8T GPS + HMC5983 compass (XL)	HERE GNSS	Zubax GNSS 2
Link	https://www.getfpv.com/3dr-ublox-gps-with-compass-kit.html	https://store.mrobotics.io/mRo-GPS-u-Blox-Neo-M8N-HMC5983-Compass-p/mro-gps004-mr.htm	https://drotek.com/shop/en/u-blox/808-ublox-neo-m8t-gps-hmc5983-compass-xl.html	http://www.hex.aero/?product=here-gnss	https://shop.titaneliteinc.com/index.php?route=product/product&product_id=987
GPS Chipset	uBlox Lea 6H	uBlox NEO-M8N	uBlox NEO-M8T	uBlox M8N	uBlox MAX-M8Q
Communication Type	Serial (I2C for compass and barometer)	Serial	Serial	Serial	Redundant CAN bus; UART; USB
Integrated Barometer?	Yes	No	No	No	Yes
Redundant Communication	No	No	No	No	Yes
Advertised Data Refresh Rate	5Hz	Unknown	1Hz (default)	Up to 10Hz	Up to 15Hz
Retail Cost (US Dollars)	$89.99	69.90	$94.51	$48.00	$129.00

Table 6: Publicly reported GNSS receiver reference information

7. Additional Testing.

The primary purpose of this paper is to illustrate the out-of-the box, manufacturer configured device performance. Two additional tests were performed after configuring each GNSS receiver to record perceived horizontal position accuracy, as labeled in the uBlox U-Center program as "PACC H". Similar to the previous test setup mentioned in this paper, the first test consisted of an "open sky", relatively obstruction free bench test. Following this was an extreme, close proximity test where the GNSS receivers were bench tested next to a commercial building.

A. Test Environment & Parameters.

1. The following test results were observed in the following environment conditions:
    a. Sky condition: Overcast
    b. Temperature: 50 degrees F (10 degrees C)
    c. Humidity: 58%
    d. Dew point: 36 degrees F (2.2 degrees C)
2. Results were based on observations recorded after at least a 5 minute period.
3. Observations and testing was performed first, approximately 35 feet (10.6m) from a commercial building. Next, observations and testing were performed approximately 3 feet (0.9m) from a commercial building. The exterior of the building and visible features are constructed primarily of concrete, steel and aluminum.

B. Results.

	mRo GPS uBlox Neo-M8N	**Zubax GNSS 2**	**Drotek uBlox NEO-M8T GPS + HMC5983 compass (XL)**	**HERE GNSS**	**3DR GPS**
Average Horizontal Position Accuracy Reported by Receiver (PACC H) - Meters	1.20	0.65	Not available	1.05	0.95
Minimum Horizontal Position Accuracy Reported by Receiver (PACC H) - Meters	1.10	0.53	1.04	0.96	0.71

Table 7: Estimated Horizontal Position Accuracy Reported – Far from obstructions

	mRo GPS uBlox Neo-M8N	Zubax GNSS 2	Drotek uBlox NEO-M8T GPS + HMC5983 compass (XL)	HERE GNSS	3DR GPS
Average Horizontal Position Accuracy Reported by Receiver (PACC H) - Meters	3.39	1.98	2.58	3.33	4.57
Minimum Horizontal Position Accuracy Reported by Receiver (PACC H) - Meters	2.77	1.62	2.19	2.73	4.11

Table 8: Estimated Horizontal Position Accuracy Reported – Extremely close to building

C. Log files. The log files from each test period may be downloaded and opened using the uBlox U-Center program.

Device	Manufacturer / Designer	Model	Log File Download Link (Relatively Obstruction Free)	Log File Download Link (Extreme Building Proximity)
1	3D Robotics	3DR GPS + Compass	http://titaneliteinc.com/share/public/7a7240	http://titaneliteinc.com/share/public/fdfb7a
2	mRo (Mayan Robotics)	mRo GPS uBlox Neo-M8N	http://titaneliteinc.com/share/public/93146c	http://titaneliteinc.com/share/public/377872
3	Drotek	uBlox NEO-M8T GPS + HMC5983 Compass (XL)	http://titaneliteinc.com/share/public/1d577c	http://titaneliteinc.com/share/public/f3289d
4	Hex / Proficnc	HERE GNSS	http://titaneliteinc.com/share/public/4adf99	http://titaneliteinc.com/share/public/9ea49b
5	Zubax Robotics	Zubax GNSS 2	http://titaneliteinc.com/share/public/fcb9b5	http://titaneliteinc.com/share/public/6f7121

Table 9: uBlox U-Center Log Files

4. Conclusion.

It appears that the majority of devices tested do not perform as stated by the designer/manufacturer in a bench test environment. The largest discrepancy of "advertised specifications" versus "actual observation" involves the use of GNSS constellations enabled and used. This is important to note because a higher number of satellites observed and used could lead to a better position estimate.

When choosing a GNSS receiver for your autopilot, mission critical applications could also benefit from factors including:

- data communication type
- redundant communication capability
- actual real-world performance (i.e. how the device reports position data when subjected to structural or environmental interference)
- how the device performs given EMI produced by neighboring equipment
- data refresh rate
- additional sensors that improve the accuracy of data being processed by the autopilot (i.e. barometric pressure sensor or magnetometer)

It appears that each manufacturer's published product data focuses on the uBlox chipset installed on the receiver, however the capabilities of the particular chipset must be realized in design and configuration (i.e. if a uBlox chipset states that it can concurrently track 3 satellite constellations, the manufacturer/designer should actually enable those constellations for the benefit of the end user).

Since this document is not a comprehensive analysis, it is important to validate these observations in your actual working environment and consider the maximum limitation of each device before use. When selecting the best receiver for your application, if a trial-and-error approach is impractical, consider the observations from this report when purchasing a select receiver (or receivers). Environmental conditions and related hardware in your end-product ecosystem will impact the actual performance of each GNSS receiver. The observations made in this document have been acquired either from public-facing manufacturer/designer resources or from uBlox U-Center log reports (available to download in *Table 5 and 9*).