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An Introduction to Testing Navigation and Positioning Performance in Drones, UAS and UAVs

A Spirent eBook for Test Engineers and R&D Teams

Introduction: The Rise of UAVs

The use of unmanned aerial vehicles (UAVs) is starting to take off in commercial and military sectors. The potential applications of UAVs are many—including survey, mapping, media reporting, delivery, reconnaissance, conservation and search & rescue.

The economics are also extremely appealing. The Hampton Roads chapter of the Association for Unmanned Vehicle Systems International (AUVSI) has done an extensive cost comparison of using unmanned vs. manned aircraft for a range of tasks, in some cases finding the unmanned system as much as 98.8% cheaper.

But it is still relatively early days, and for designers and developers of UAVs, there remain many challenges in bringing viable models to market and putting them to work.

Challenges for UAV designers and developers

For example, these small, light and unpiloted aircraft must be able to cope alone with a wide range of weather, environmental and RF signal conditions. They must know their own position and altitude at all times, and be capable of navigating a course accurately and returning to base safely.

They must also stay on the right side of industry regulations, many of which are just starting to be formulated, differ from jurisdiction to jurisdiction, and evolve very fast.

And that's just when things are going to plan. To be truly useful in the real world, UAVs must also be able to recognise when something has gone wrong, and either remediate accordingly or alert a human operator and act on that person's instructions. And, in addition to flying to their destination and back again, they must be able to do their intended job properly: whether that is delivering items to a specific destination intact, or accurately time- and location-stamping photographs and footage.

All of these factors present considerable challenges to project teams tasked with improving and verifying a UAV's positioning capabilities during R&D and commercial production.

Spirent can help

As the world's leading test and measurement company for location-aware devices, Spirent is working with commercial and military drone developers worldwide to design test regimes that combine maximum rigour with minimum time and cost.

In this ebook, we set out some of the main positioning and navigation considerations that UAV test teams will need to incorporate into their test regime—in terms of the overall design of the UAV; the accuracy and reliability of the chosen GPS/GNSS receiver; the impact of the external environment on the UAV's performance; and compliance with emerging regulations.

Finally, we provide insight into how Spirent's simulators and expertise can reduce the time, cost and effort of testing the navigation and positioning-related elements of your UAV's performance.

If you would like to talk to Spirent about help with testing your commercial or military UAV design, please do get in touch using the details below. We look forward to hearing from you.

SECTION 1:
GPS/GNSS Performance Considerations

A critical step for any UAV design team is the evaluation and selection of the most appropriate GPS or GNSS receiver for the vehicle.

There are many receivers available on the market, with huge differences in cost, sophistication, precision and accuracy. Spirent would always advise design teams to conduct their own independent testing of individual chipsets or receivers, rather than rely purely on the manufacturer's spec sheet.

Test teams will want to consider a multitude of performance aspects, many of which will depend on the intended real-world use of the UAV. For example, a UAV designed for precision surveying will require a far higher degree (e.g. sub-10cm) of positioning accuracy than a UAV designed for parcel delivery (e.g. sub-1m).

Fundamental tests in this category include:

Time to First Fix: Time To First Fix (TTFF) is a measure of how quickly a receiver performs the signal search process. Test teams will want to understand how quickly after power-up the receiver can obtain its first valid navigational data point: both for the first time (Cold Start TTFF), and when earlier position information has been retained (Warm/Hot TTFF).

Acquisition sensitivity: The minimum received power level at which a 'First Fix' can occur. The sub-sets of this are separate measurements for each of the cold, warm and hot start-up conditions.

Tracking sensitivity: The minimum power level at which a receiver can continue to maintain lock.

Reacquisition Time: The time necessary for a receiver to regain its first valid navigational data point after total loss of all received signals (for example after a period in a GNSS-denied area).

Static Navigation Accuracy:
The accuracy to which a receiver can determine its position with respect to a known location.

Dynamic Navigation Accuracy: The same as Static Navigation Accuracy, except the receiver is undergoing motion in any or all of the three axes of movement x, y, z.

Timing accuracy: The accuracy to which the receiver can determine the time based on timing information received in the satellite signal–for accuracy of timestamping of photographs or video footage.

All of these tests can be performed quickly, accurately and repeatably in the lab using a GPS or GNSS simulator to mimic the position data emitted by overhead satellites and monitor the effects on the receiver.

There are significant advantages to using a simulator over 'live' satellite signals, including full control over the signal, complete repeatability of the test conditions, and the ability to simulate signals from future satellite constellations and frequencies. You can read more about using simulators for GNSS receiver performance testing in Section 5 of this ebook.

SECTION 2:
UAV Design Considerations

UAVs are, by necessity, light vehicles that are intended to do relatively robust work autonomously. To ensure they can do that work properly, the overall design of the drone is critical. There are critical design differences in play between, for example, a drone whose main purpose is to hover for long periods over a specific location (e.g. for surveying or mapping), and a drone whose main purpose is to fly quickly to and from a specific destination, with minimal hover time (e.g. for delivery).

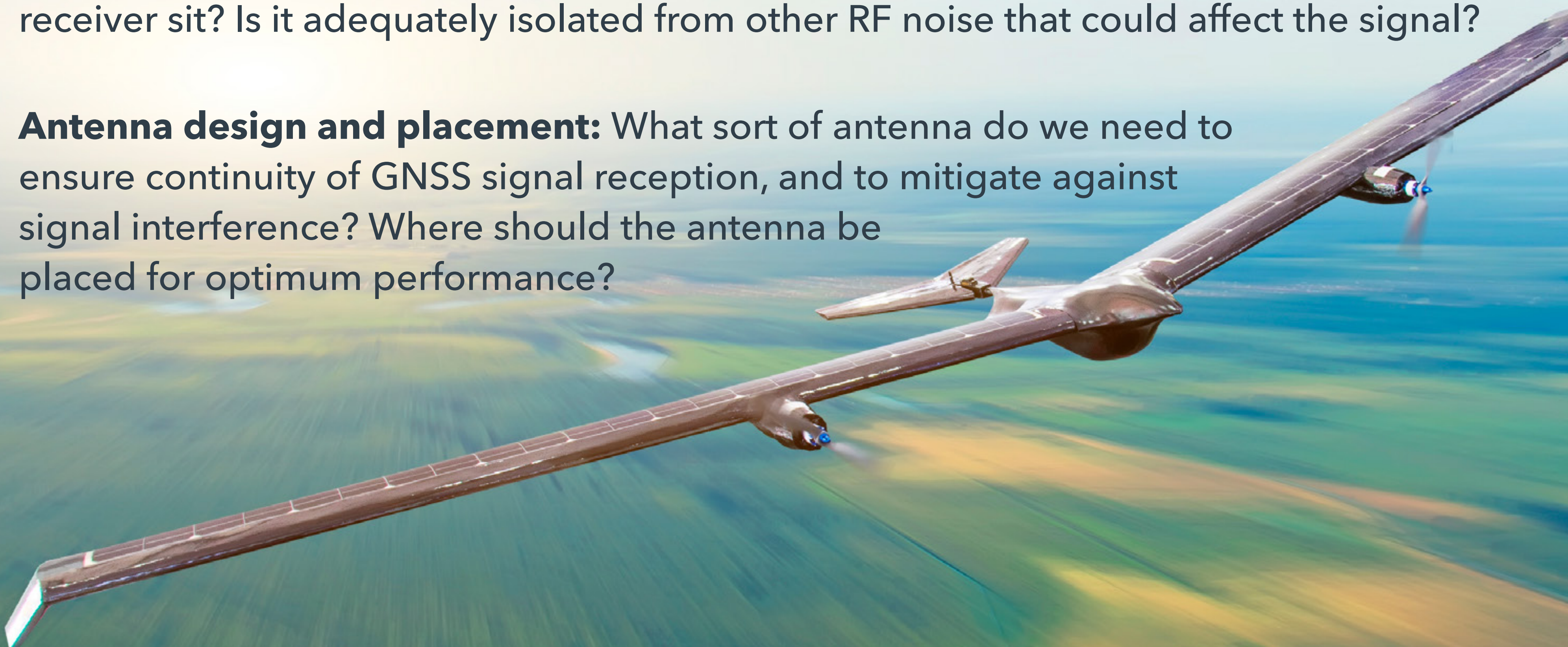
These considerations have led to the emergence of two main categories of drone; rotary-wing and fixed-wing. In addition, these categories have multiple sub-categories, such as vertical take-off and landing (VTOL) and medium altitude long endurance (MALE).

From a positioning and navigation point of view, test teams must incorporate adequate circuitry into the overall design, and ensure that the design doesn't hinder the ability of that circuitry to receive satellite and augmentation/correction signals, or to calculate an accurate and continuous position from them.

Test considerations in this category include:

GNSS chipset or receiver placement: Where within the design should the GNSS receiver sit? Is it adequately isolated from other RF noise that could affect the signal?

Antenna design and placement: What sort of antenna do we need to ensure continuity of GNSS signal reception, and to mitigate against signal interference? Where should the antenna be placed for optimum performance?



Selection and placement of positioning sensors: What additional sensors–e.g. MEMS, IMUs - are needed to ensure continuity of positioning and navigation? Where should they be placed? Does the data from those sensors align with the satellite position data for coherent output?

Impact of movement of the aircraft: Does the vibration of the aircraft and its movement in three dimensions (roll, pitch, yaw) affect positioning accuracy and performance?

Recognition and response to error states: Can the positioning system recognise and appropriately correct for error states, such as the aircraft flying upside-down?

Many test teams feel there is no option but to test these conditions with real-world test flights. But in reality, much of this can be tested using simulators in the lab.

Simulation not only speeds up and lowers the cost of testing, but also allows for a wide range of theoretical conditions to be tested rigorously and repeatably. That repeatability makes it much easier to isolate issues that are specific to the design, rather than the external environment, and to make adjustments accordingly.

And while simulation can't completely replace the need for test flights, those flights can be made much more efficient by using a Record & Playback system (RPS) to capture live flight data and replay it later in the lab. You can read more about Spirent's simulators and RPS solutions in section 5.

SECTION 3:
Environmental Considerations

It's not just the design of the drone itself that has a bearing on its ability to calculate its position, hold a position, and navigate accurately in the real world.

A multitude of external factors can significantly affect these abilities, and test teams will want to test the performance of their design in as many of these conditions as possible.

Critical considerations for designers and test teams include:

Wind: Can the UAV quickly regain its intended position if blown off course by the wind?

Temperature changes: Do the GNSS antenna and receiver continue to function as expected in extreme temperatures, or rapid changes in temperature?

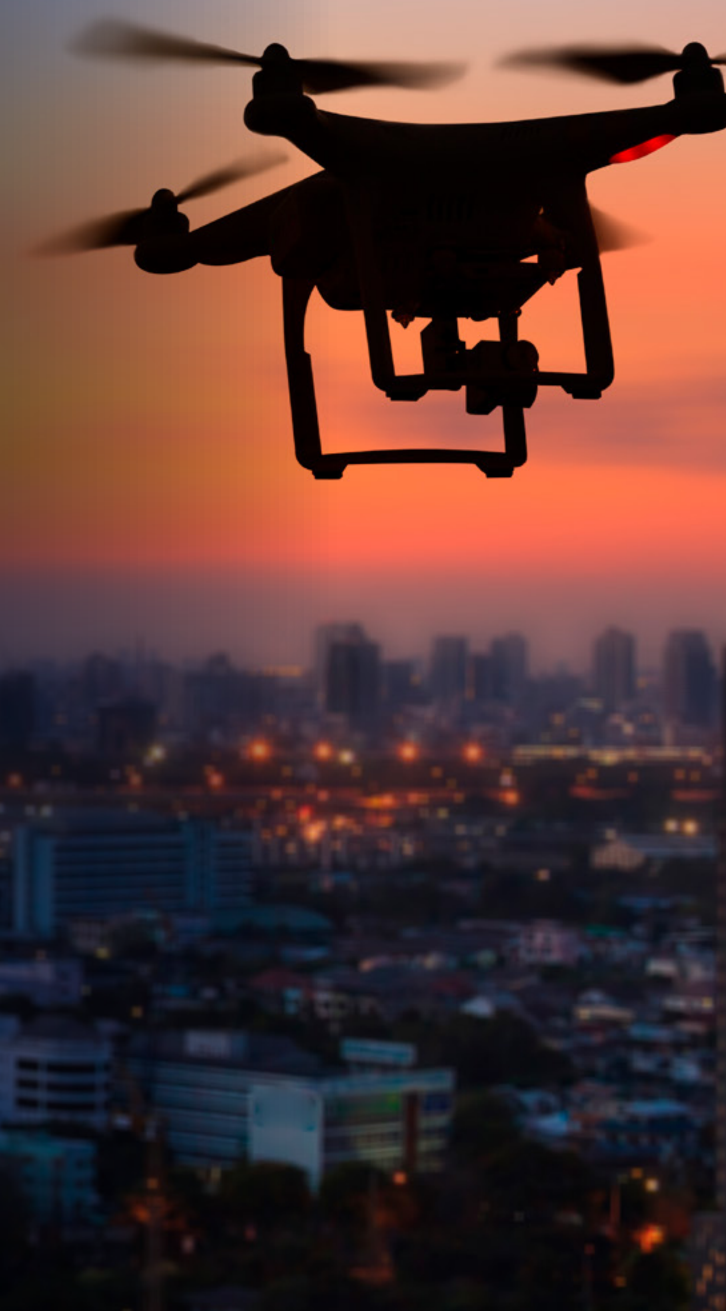
Signal obscuration: Can the UAV still generate an accurate position when signals from one or more satellites are obscured by objects in the environment (e.g. mountains, tall buildings, tree cover, high-sided cuttings)?

Signal denial: Can the UAV continue to generate an accurate position when GNSS signals are completely denied (e.g. indoors, during signal outages)?

Multipath effects: Can the UAV recognise and correct for 'multipath' effects caused by the GNSS signal bouncing off tall buildings?

Latitudes near the poles: If flying at high latitudes where there are fewer or no satellites overhead, can the vehicle still calculate its own position accurately?

RF interference: Can the UAV detect and correct appropriately for a wide range of potential sources of radio-frequency interference, including noise from nearby transmitters; deliberate or unintentional jamming; deliberate spoofing; and atmospheric interference?



A wide range of simulation solutions are available to support extensive lab-based testing for these kinds of environmental factors. See section 5 for more information.

SECTION 4:
Compliance Considerations

With UAVs still in their infancy, many regulations governing their use are still being formulated.

Currently, regulations differ from geography to geography, and are likely to evolve rapidly as UAVs become more prevalent, are used for a widening array of applications, and lawmakers and the general public become more (or indeed less) comfortable with their existence.

The incomplete state of current legislation creates challenges for developers looking to bring viable and compliant models to market. Designs will need to be able to comply with current and likely future legislation, or at least be easy to upgrade to account for future rules and regulations.

From a positioning point of view, two main strands of current legislation will have a bearing on testing programs:

Geofencing: Drones are already being excluded from certain areas—including airports and public parks—through the use of geofencing, with potentially heavy penalties for illegally entering 'no-drone zones'. Test teams will want to thoroughly test whether the drone can accurately recognise when it is approaching a no-fly zone and react accordingly.

Altitude restrictions: Altitude boundaries will become increasingly prevalent, to separate drone traffic from other airspace users. Test teams will need to ensure the drone can accurately calculate its own altitude at all times, and take corrective action if it flies too high or too low.

In future, it's not hard to imagine that drones will be increasingly restricted to narrow 'air corridors' to ensure they don't disrupt other airborne or ground-based operations. And safety features, like the ability to recognise when they are close to other objects, and take appropriate evasive action, will almost certainly be incorporated into future standards for UAV performance.

Simulation can help test teams to quickly and efficiently evaluate the performance of the UAV in light of these and other restrictions—and to identify shortcomings in the design that need to be addressed.

SECTION 5: **Introducing Spirent Test Solutions for UAVs**

Spirent simulation and record & playback solutions enable all the tests outlined in this ebook to be conducted professionally, quickly, and accurately—and at significantly lower cost than repeated live test flights.

Spirent simulation solutions for UAV design and development teams include:

GSS9000 Multi-Frequency, Multi-GNSS RF Constellation Simulator produces a comprehensive range of emulated multi-GNSS, multi-frequency RF signals with ultimate class-leading flexibility, coherence, fidelity, performance, accuracy and reliability. Generated signals include, for approved users, a range of restricted signals.

GSS7000 Multi-GNSS Constellation Simulator supports any combination of current and future GNSS signals and frequencies (excluding restricted signals). It provides accurate, repeatable, combined multi-GNSS signals, and can be configured with up to 256 channels.

GSS6300M Multi-Channel, Multi-GNSS Simulator is the ideal entry-level multi-channel GNSS simulator for busy receiver integrators, application developers, aftercare and production testing environments. Its 4 or 8 channels of operation can simulate L1/E1 signals from GPS/SBAS/QZSS, GLONASS, BeiDou and Galileo to test the fundamental positioning capabilities of any GNSS device.

GSS7765 Interference Simulation System is a ready-to-use integrated interference signal generator. Combined with one of Spirent's GNSS satellite constellation simulators, it offers a comprehensive solution for testing satellite navigation receivers in the presence of RF interference.

SimGEN is Spirent's fully flexible simulator software suite. It offers a comprehensive scenario generation capability—including control of the constellations, propagation, terrain obscuration, antenna patterns, multipath, vehicle trajectory and a range of error models.

SimSENSOR enables the controlled and progressive testing of sensor fusion algorithms for the integration and optimisation of Multi-GNSS and MEMS inertial sensors.

SimINERTIAL enables laboratory simulation of integrated GNSS and Inertial systems and inertial measurement units (IMU).

GSS6450 Record & Playback System is the world's first highly portable high bit-depth RF record and playback system. Despite small form factor, and weighing just 2.2kg, it enables the capture of GNSS signals, atmospheric and interference events, and a range of additional signals within the frequency range. These environments can then be replayed repeatedly in the lab, offering an accurate representation of real-world testing.

UAV Testing in Action

A leading Chinese manufacturer of UAVs for commercial use wanted to test the performance of the GNSS receivers in their model, which is used for precision aerial surveying. Using the Spirent GSS9000 simulator, the company was able to model a range of real-world conditions to test the performance of the UAV's Novatel GNSS receivers.

They were particularly interested in understanding how well the receiver would cope with high winds, multipath effects, atmospheric interference, signal obscuration, and the vibration and tilting of the UAV in flight. Using the GSS9000 it was able to simulate all of these conditions to characterise the performance of the receiver. The company is also using RPS to record and replay live test flight data in the lab, removing the need for additional test flights.

Summary and Next Steps

Bringing a viable UAV to market for commercial or military use presents many challenges for test teams at all stages, from R&D through to production. These unmanned aerial vehicles are heavily dependent on satellite-based positioning technology, and anything that impacts the GNSS receiver's ability to do its job will, in turn, impact the UAV's ability to fulfil its own intended purpose.

As a result, testing of the positioning capabilities of the craft must be thorough, rigorous and broad, to ensure that as a wide a range as possible of potential real-world conditions have been applied. This is only possible with a test program that incorporates lab-based simulation and record & playback along with live flight testing.

If you would like any help, advice or information about using simulators and record & playback systems to test your UAV design, Spirent will be happy to help. You can contact us using the details below.

About Spirent

About Spirent Communications

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges.

Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

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For more about how to choose the simulation environment that's right for you, read our eBook: **Choosing a GNSS Simulator.**

We are always adding new content to our website. Bookmark this link: **www.spirent.com/positioning**

Visit the Spirent Positioning Blog, or LinkedIn page, where we regularly provide information on new developments.

Need more information?
Contact us.

MCD00227 1-02 | Rev B | 10/19