

1 General Description

The Millswood Engineering Aerofence is a sophisticated geofencing device that comes in a tiny form-factor.

A 3D geofence is a volume of airspace, often defined by an area and a pair of altitude limits. The Aerofence supports 2 independent polygonal geofences, each consisting of up to 50 vertices. Areas may contain exclusion zones (also polygonal) within them.

The Aerofence monitors an NMEA data stream, extracts 3D position fix information, and calculates whether or not the 3D fix lies within the pre-defined volume(s) of airspace.

Please note that the Aerofence **does not** include a GNSS receiver – most GNSS receivers have a logic-level serial output which is suitable for connection to the Aerofence.



Geofence status is reported with dedicated bi-colour LEDs and logic-level outputs. GNSS status is reported in the same way.

Although the Aerofence was designed with unmanned aviation in mind, it can be used in any application that requires a deployable geofence.

The Aerofence is 1.075 x 1.075" (27.3 x 27.3mm) and weighs 0.15oz (4g).

2 Why use an Aerofence?

Geofences are becoming ubiquitous. Some autopilots have them, some ground control stations have them, even some smartphones have them. But they often come with a few problems...

1. **Limited geometry** – many implementations only offer circular geofences. This severely restricts the opportunities for deploying geofencing technology.
2. **Wrong device location** – for maximum reliability the geofencing device must be located on the vehicle itself, and processed locally. Distributed geofencing is often easier, but it does make the geofence vulnerable to loss of comms.
3. **Poor user interface** resulting in an error-prone work flow. This is a safety risk – aircraft have been lost because of poor user interface design.

The Aerofence solves the first two problems by offering sophisticated polygonal geofencing in a tiny form-factor. The third problem is solved by the graphical geofence designer within the Aerofence configuration utility. Download it and discover how easy it is to create simple and complex geofences.

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4 Connectors

The Aerofence has two connectors: a micro USB connector for configuration, and a 6-pin JST ZH series connector for operational use. The pinouts of the JST connector are as follows:

Pin	Function
1 Main Power	Positive power supply input (reverse polarity protected)
2 Ground	Ground
3 GNSS in	Logic-level input, receives asynchronous serial data
4 GNSS OK	Logic-level output, indicates presence of 3D position fix
5 GF1 OK	Logic-level output, indicates location of fix with respect to geofence 1
6 GF2 OK	Logic-level output, indicates location of fix with respect to geofence 2

Table 1 – Pinouts

The USB connector is intended for configuration only – it is not needed during normal operation, although it can be useful for initial setting up and testing.

The wire colours on the mating JST harness have no significance and may vary from batch to batch. Do not assume that red is power and black is ground – they will probably not be!

5 Operation

The Aerofence has a single digital input which accepts NMEA-formatted GNSS data. Position fix information is derived from the NMEA “GGA” string.

The Aerofence has 3 logic-level digital outputs and 3 corresponding LEDs. Operation of the Aerofence is defined by the following truth table, where GF_n represents either geofence 1 (GF1) or geofence 2 (GF2).

GNSS in	GNSS OK	GNSS LED	GF _n OK	GF _n LED
No signal	Low	Red	High-Z	Off
NMEA messages, but no 3D fix	Low	Red/Green	High-Z	Off
3D fix present, GF _n not defined	High	Green	High-Z	Off
3D fix present and inside GF _n	High	Green	High	Green
3D fix present and outside GF _n	High	Green	Low	Red

Table 2 – Operational truth table

GNSS receivers can take many seconds to acquire a 3D fix. During this time the GNSS LED will toggle between red and green to indicate that NMEA messages are being received by the Aerofence. This provides visual confirmation that the correct Baud rate has been chosen.

There is a 3 second expiry time on position fix information, i.e. if the position is not updated for 3 seconds, the Aerofence will deem the GNSS signal to be absent.

The geofence outputs should be connected to inputs that include either a pull-up or a pull-down resistor. This defines the behaviour of the output when it becomes high-impedance. The GNSS OK output is always low-impedance and does not need a pull-up or pull-down (although no harm will come from including one).

*Pull-up or pull-down resistors should be **at least** 3.3kΩ. Values in the range 4.7kΩ to 100kΩ generally work well.*

6 Configuration Utility

The configuration utility is a Windows application that allows configurable parameters to be read from and written to the Aerofence. Parameters can also be saved to file and retrieved for later use. The file format is XML, and so Aerofence parameter files can be inspected using any browser or text editor.

To configure the Aerofence, simply connect it to your computer via a USB cable and run the configuration utility. The Aerofence will power itself from the USB connection (although no harm will come from powering it externally at the same time).

The main page of the configuration utility consists of tabbed pages, and there is a menu across the top. The "Connection" menu allows selection of the serial port to which the Aerofence is connected. Once connected successfully, the "Device" menu will become accessible. This menu allows reading and writing to the Aerofence, as well as viewing its serial number and upgrading its firmware.

Note: If the USB connection is dormant for an extended period of time, the Aerofence will power down its USB connection: simply unplug it and plug it back in if this occurs.

There are 5 tabbed pages as follows:

6.1 About

The "About" tab displays the current software version number of the configuration utility (not the Aerofence device).

6.2 General

The "General" tab allows configuration of the GNSS Baud rate and LEDs.

6.2.1 GNSS

The GNSS Baud rate should be set to the same rate as your GNSS receiver's serial data output.

6.2.2 Options

If the Aerofence is fitted in a location where the LEDs are not visible, they can be disabled to save current. The GNSS LED will still illuminate (red) when the Aerofence is first powered up, but it will extinguish after a few seconds.

6.3 Geofence 1 and 2

The Aerofence implements geofences as volumes of airspace defined by polygonal areas and altitude limits (upper and lower). The Aerofence supports 2 independent geofences, each consisting of up to 50 vertices. Areas may contain exclusion zones (also polygonal) within them.

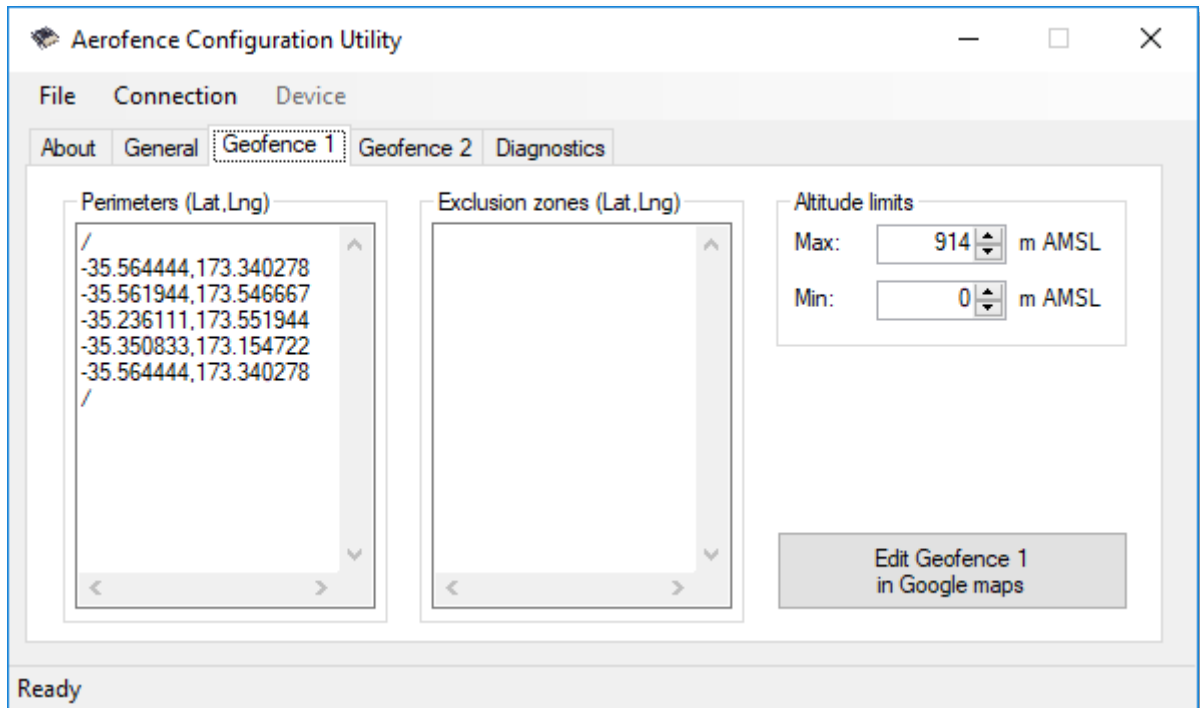


Figure 1 – Editing geofence 1 manually

Geofences can be defined by entering latitude-longitude coordinate pairs into the Perimeters and Exclusion zones boxes. When entering data this way there are a number of rules that must be observed:

- Latitude and longitude must be given in decimal degrees,
- Shapes must be closed (i.e. the first vertex must be repeated at the end),
- Shape outlines must not cross themselves or other shape outlines within the same geofence,
- Perimeter vertices must be listed clockwise, exclusion zone vertices anticlockwise,
- Shapes must be delimited by forward slashes ("/"), with each forward slash on its own line.

The main reason for entering data in this tedious and potentially error-prone way is if coordinate data is available electronically, and can be cut and pasted in. Generally it is simpler and safer to create a geofence in the embedded Google Maps geofence editor (described in the next section), where shapes can simply be drawn and edited on a map.

6.3.1 The Google Maps geofence editor

The Google Maps geofence editor provides a simple but powerful way to create and edit geofence areas. (Altitude limits still need to be entered from the parent Geofence tab). The geofence editor is opened by clicking the “Edit Geofence in Google maps” button on the Geofence tab. An internet connection is required.

Map display tools are located in the top left-hand corner of the geofence editor window and drawing tools are located in the top right. Current latitude and longitude are shown in the status bar along the bottom of the window. Clicking on a geofence opens an information box.

Geofence 1 is always shown in blue and geofence 2 is always shown in green. Both geofences are always displayed but only one geofence can be edited at a time. Right-clicking on a geofence will bring up a context-sensitive menu. Note that right-clicking on the geofence’s outline is different to right-clicking on the filled area within.

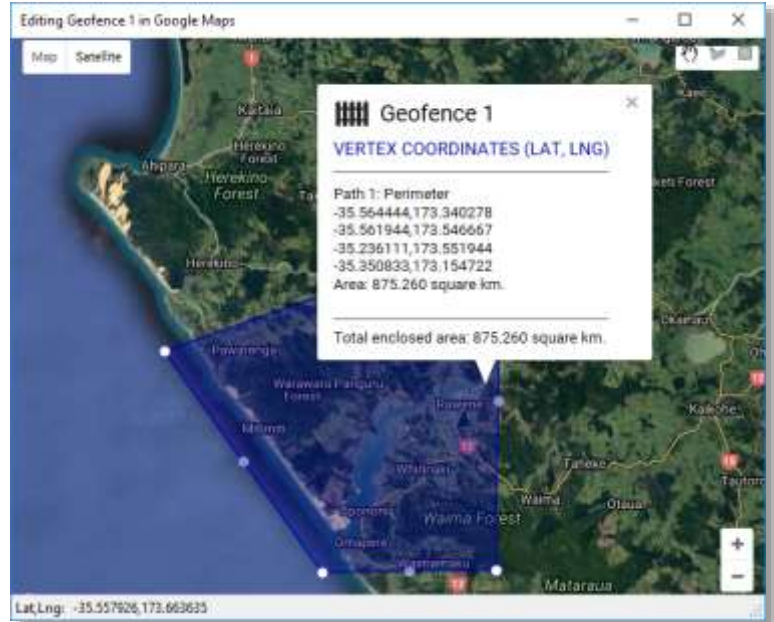


Figure 2 – Editing geofence 1 in the geofence designer

Whenever a new outline is created, the editor will do some basic error checking and if the new outline clearly crosses other outlines (within the same geofence) it will be rejected. The editor will determine whether a new outline is a perimeter or exclusion zone, but this can be changed by right-clicking on the outline.

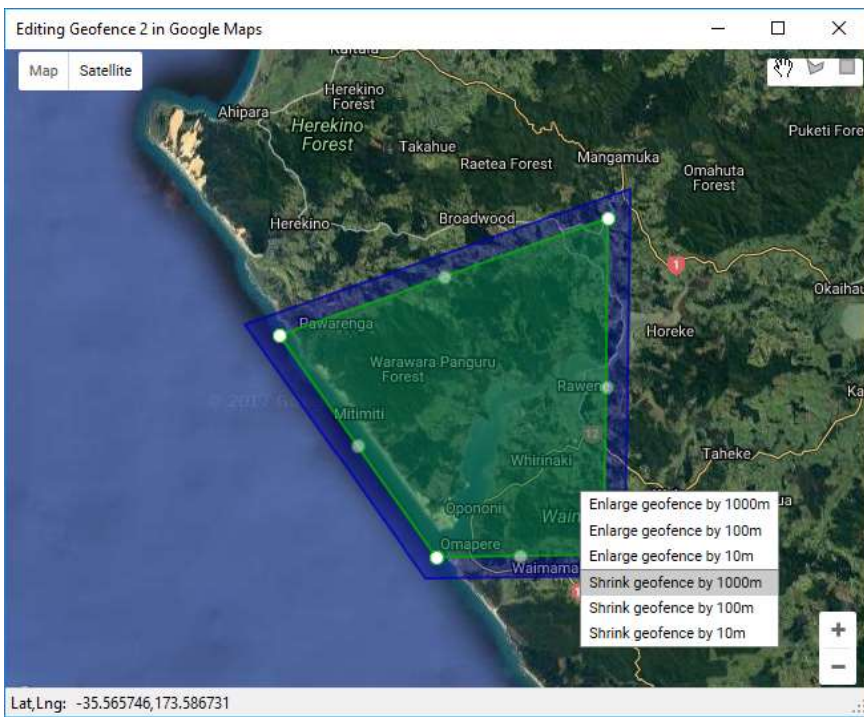


Figure 3 – Editing geofence 2 in the geofence designer

One geofence may be copied to the other by right-clicking on the geofence to be copied. This allows the creation of inner/outer geofence pairs by copying one geofence to the other and then shrinking or enlarging as required.

The screenshot on the left shows geofence 2 which has been created by copying geofence 1, and then shrinking it to form an inner geofence.

And finally, the screenshot below shows a polygonal exclusion zone carved out of geofence 1 to protect a populated area:



Figure 4 – An exclusion zone within geofence 1

6.4 Diagnostics

The "Diagnostics" tab shows the current GNSS location and the status of the outputs. These values are only meaningful if a GNSS receiver is connected to the Aerofence.

7 Specifications

7.1 Absolute Maximum Ratings *Note 1*

	Min	Max	Unit
Main Power	-15	+15	V
Digital IO (GNSS in, GNSS OK, GF1 OK, GF2 OK)	-3.5	+6.5	V

Table 3 – Absolute Maximum Ratings

7.2 Recommended Operating Conditions

	Min	Max	Unit
Main Power	+4	+12	V
Operating free-air temperature	-25	+85	°C

Table 4 – Recommended Operating Conditions

7.3 Typical Characteristics (5V, +25°C)

	Min	Typ	Max	Unit
Operating current				
LEDs enabled			35	mA
LEDs disabled			5	mA
Digital inputs (GNSS in)				
High-level input voltage	2			V
Low-level input voltage			0.8	V
Input pull-up resistance (to +3.3V)		27		kΩ
Digital outputs (GNSS OK, GF1 OK, GF2 OK)				
High-level output voltage (I _{OH} =-2mA)	2.5	3.0		V
Low-level output voltage (I _{OL} =2mA)		0.25	0.5	V

Table 5 – Typical Characteristics

7.4 Geofencing Precision *Note 2*

	Min	Max	Unit
Altitude		1	m
Location (Latitude, Longitude)		0.2	m

Table 6 – Geofencing Precision

7.5 Mechanical Characteristics

	Imperial	Metric
Dimensions	1.075" x 1.075" x 0.315"	27.3 x 27.3 x 8.0mm
Mounting hole pitch	0.85" x 0.85"	21.6 x 21.6 mm
Mounting hole diameter	0.12"	3.05 mm
Mass (excluding cable)	0.15 ounces	4 grams

Table 7 – Mechanical Characteristics

Note 1: Absolute maximum ratings are those values beyond which damage to the product may occur. Functional operation under these conditions is not implied.

Note 2: Precision specifies the resolution and repeatability of a system, whereas accuracy specifies how close a measured value is to the true value. Precision of a geofencing system is determined by both the geofencing device and the GNSS receiver, but accuracy is determined solely by the GNSS receiver.

8 Documentation change log

8.1 0.9 -> 1.0

8.1.1 General Description

- Picture updated to reflect production hardware.

8.1.2 Configuration Utility

- Comms tab name changed to General.
- Improved description of GNSS Baud rate setting.
- Added LED enable/disable feature description.

8.1.3 Specifications

- Absolute Maximum Ratings / Main Power / Min & Max voltages reduced to observe production component ratings.
- Absolute Maximum Ratings / Digital IO / Min & Max voltages reduced to observe production resistor values.
- Recommended Operating Conditions / Main Power / Voltage range reduced to observe production component ratings and regulator temperature limits under worst-case conditions (maximum ambient temperature, all LEDs on).
- Typical Characteristics / Operating current re-specified into two separate categories to reflect updated firmware.
- Typical Characteristics / Digital outputs / reference current improved.
- Geofencing Precision re-formatted into table.
- Mechanical Characteristics added.

8.2 1.0 -> 1.1

8.2.1 Operation

- Description updated to reflect firmware version 1.02 (GNSS LED toggles between red and green when NMEA messages are being received, prior to acquiring a 3D fix).

8.3 1.1 -> 1.2

- Document section numbering added.
- Appendices moved to end of document.

9 Appendix 1 – Data security and privacy

The Aerofence does not store any dynamic operational values in non-volatile memory, such as altitude, latitude or longitude as received from the GNSS receiver. The Aerofence does, however, store all of the geofence altitude limits and latitude/longitude coordinate pairs in rewriteable non-volatile memory. This data is not encrypted.

Within the configuration utility, the graphical geofence editor transmits unencrypted coordinate data to and from Google Maps using the Google Maps API. If coordinates are entered manually (without accessing the Google Maps Geofence editor) then no external transmission of coordinate data occurs.

10 Appendix 2 – Recovering from a failed firmware update

The firmware update process is robust, but it will not detect the wrong hex file being uploaded. If this happens the Aerofence will most likely become unresponsive. This is commonly referred to as “bricking” the device.

The recover from this, ground pin 3 (GNSS in) on the JST connector by connecting it to pin 2 (Ground) on the same connector, and then connect the USB cable and run the configuration utility. The Aerofence will then remain in firmware update mode until new – and hopefully correct – firmware is uploaded. Once this is complete, remove the short to ground and the Aerofence will operate normally once again.