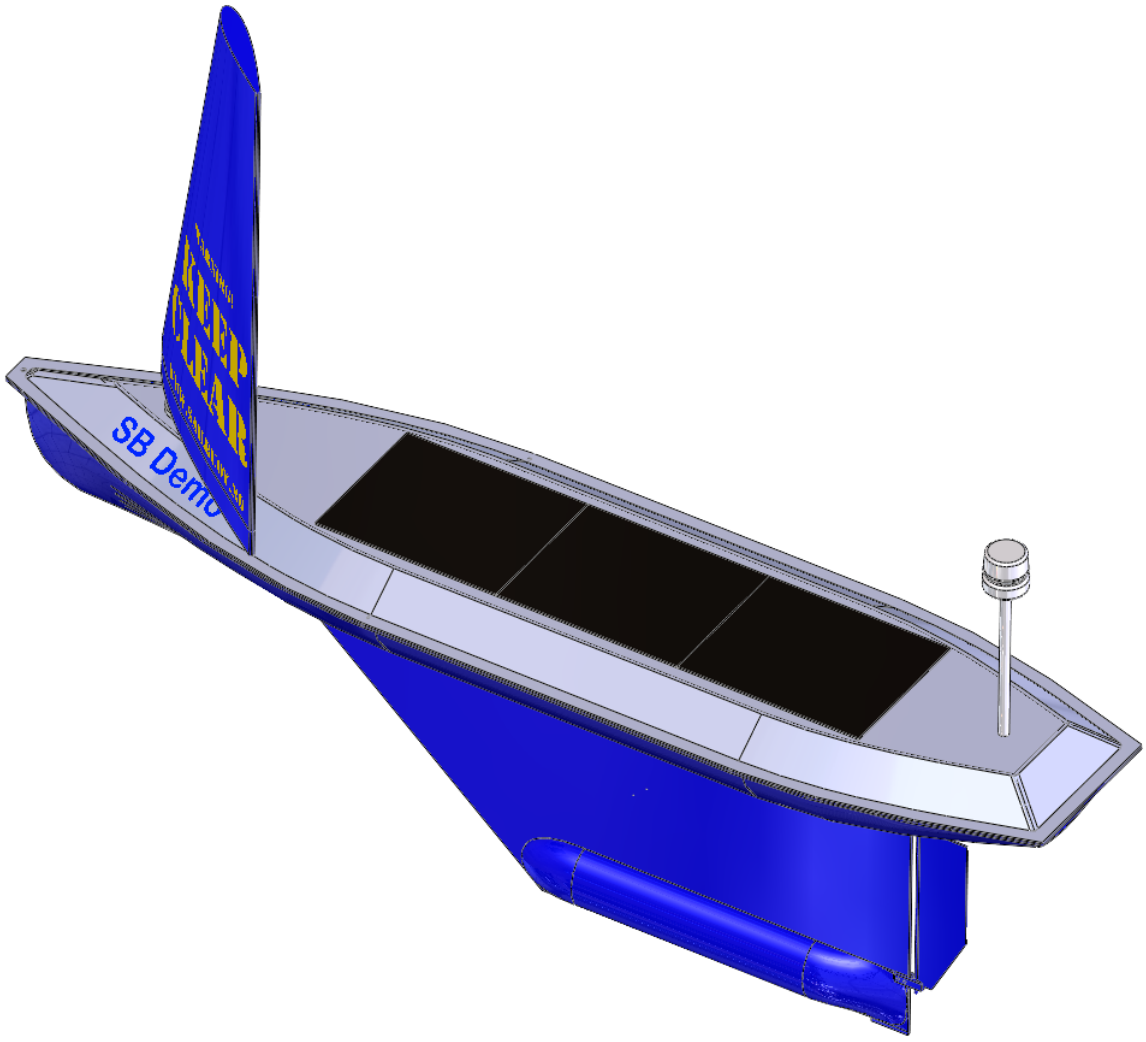
Sailbuoy Autopilot User Manual



Date: 6 April 2021
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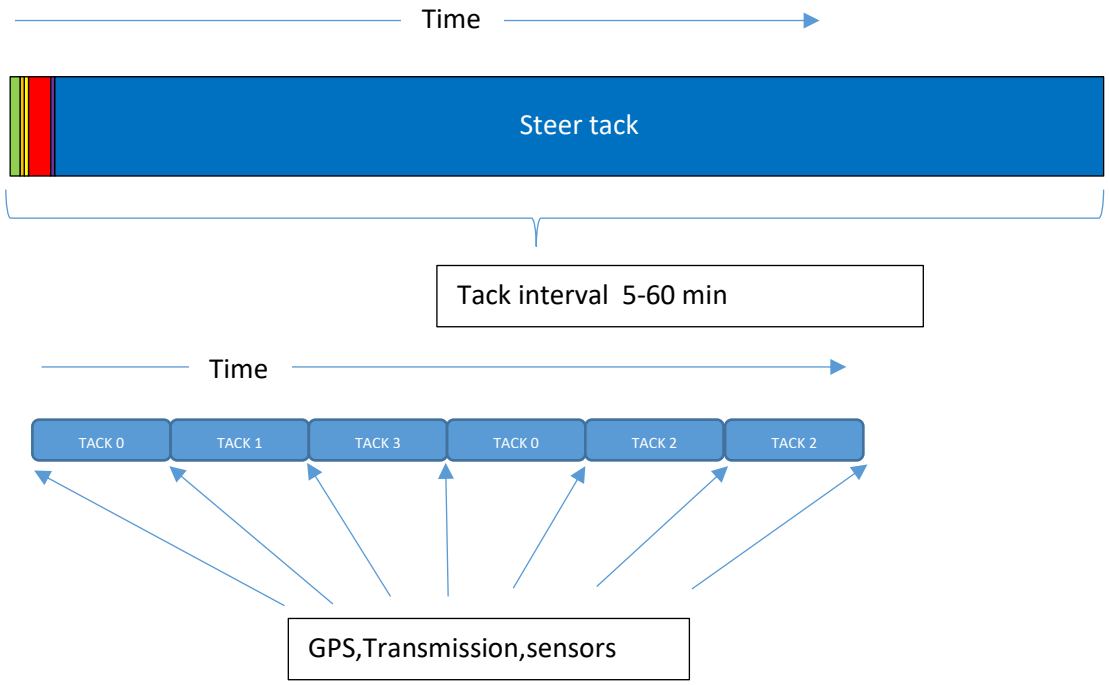
Contents

Timing

The autopilot does the flowing things in sequence.

1. Get GPS fix (10-20 sec)
2. Get internal sensor values (1 sec)
3. Calculate next tack (3 sec)
4. Send data (30-120 sec)
5. Receive commands (10 sec)
6. Steer tack (rest of the tack interval)



Basic functionality

The autopilot controls the sailing direction of the Sailbuoy by controlling the rudder. The sail is self-tacking.
The Sailbuoy is optimized to sail in 4 directions only and the autopilot selects the best suited direction of these to follow the defined track sent by the user.

Sailing tacks

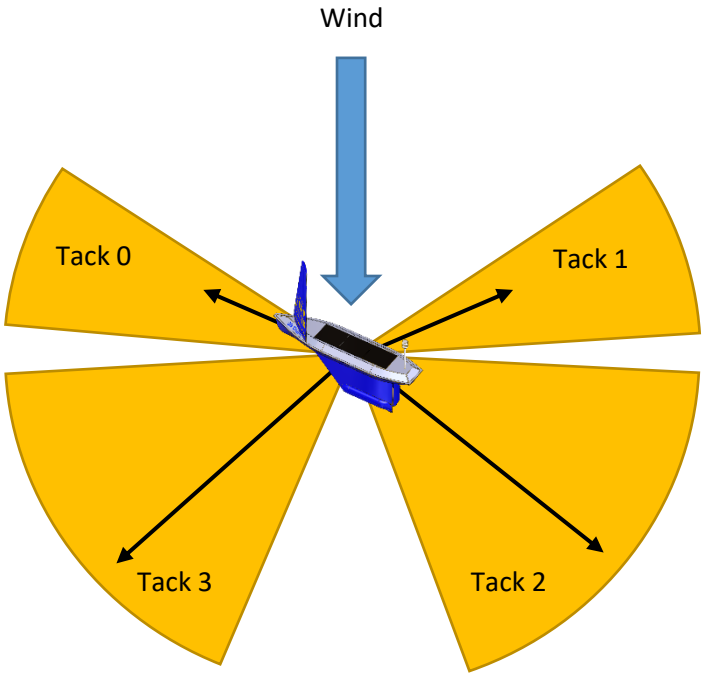
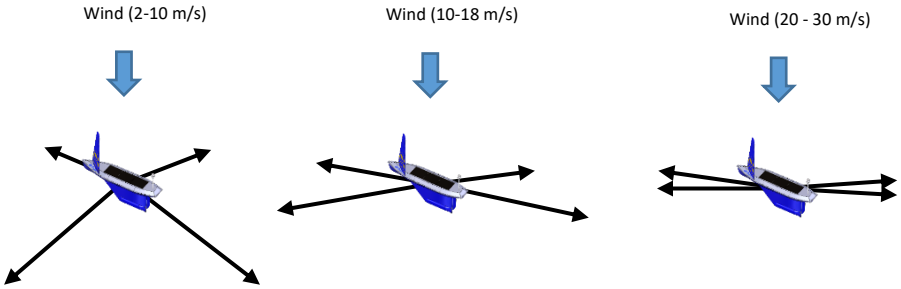


Figure 1

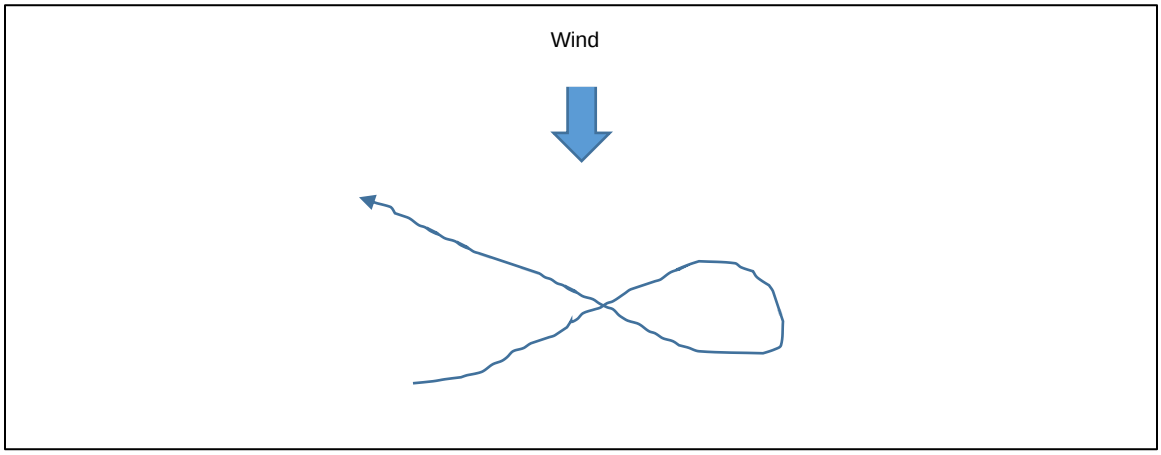
As shown on figure 1 the Sailbuoy can sail in two directions against the wind and two with the wind. It cannot sail directly against or with the wind.
The direction and speed of these tacks will vary according to the wind and wave conditions, but will always lie within the yellow sectors.



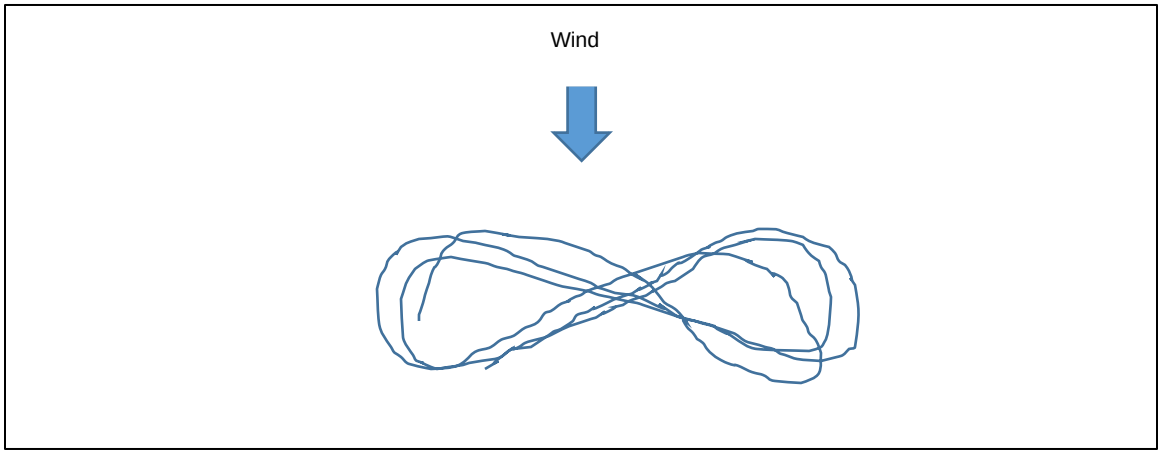
To follow the course set by the user, the autopilot will select the combination of tacks that will best fit the defined course.

Tacking

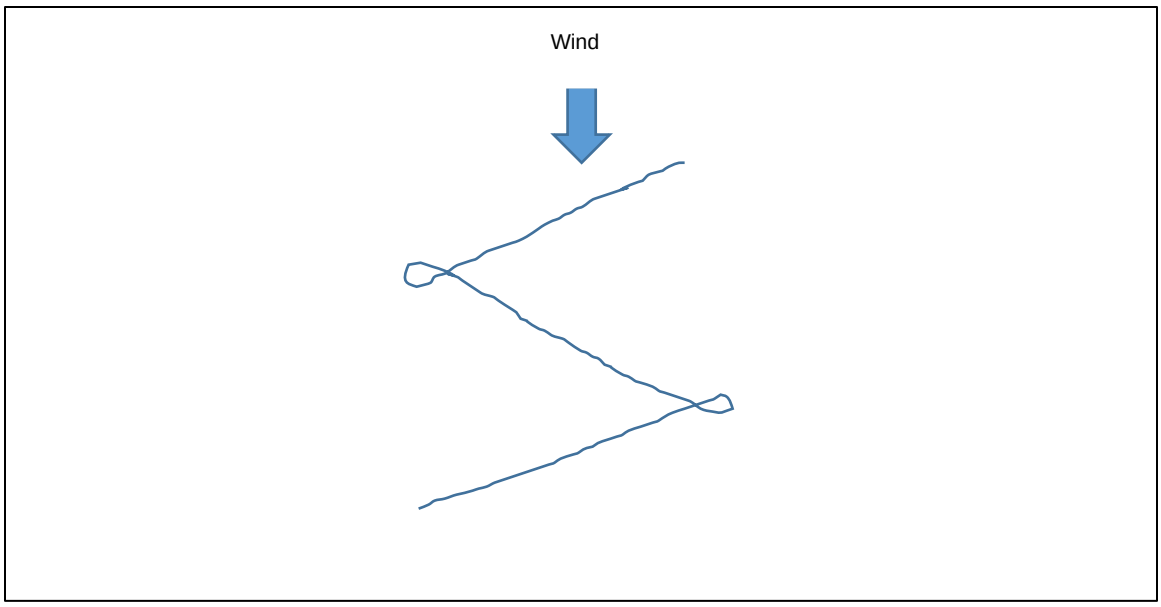
When the Sailbuoy changes direction, unlike modern sailboats it always gybes. Doing this maneuver, it will lose some ground if going against the wind. If the tack interval is set too short (5 min). It will lose more ground gybing than it will gain on the tacks and will end up doing a figure 8 and getting nowhere. It is therefore important not to set the tack interval too short (5 min) but longer (30 min- 1 hour) to keep losing ground due to gybing as little as possible.



A Sailbuoy gybe.



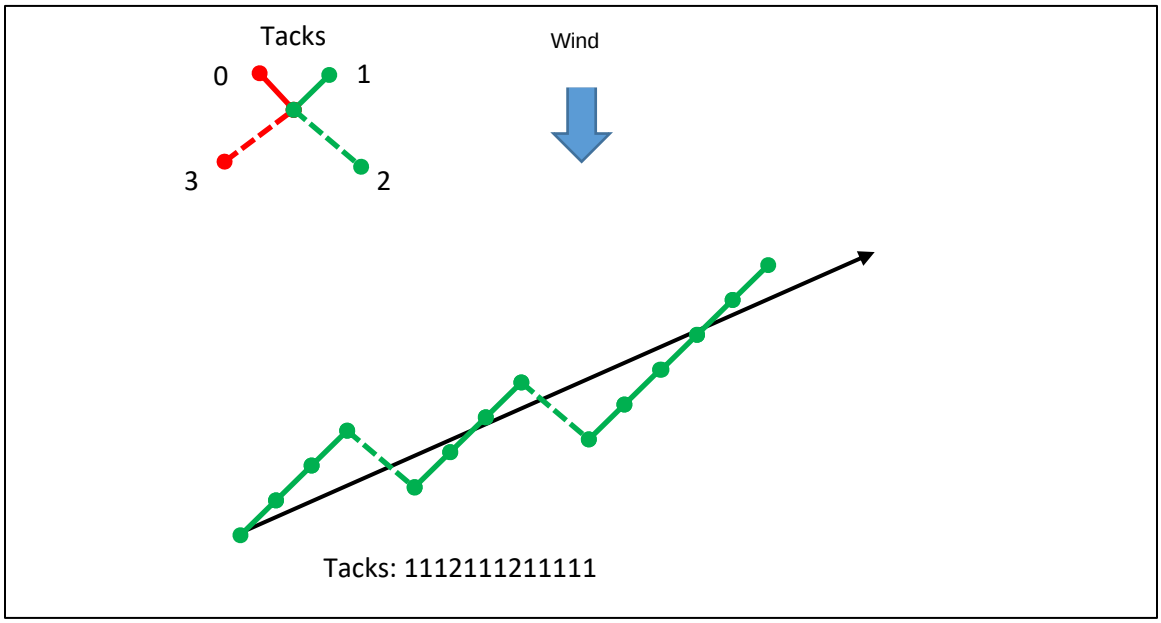
5 min tack interval

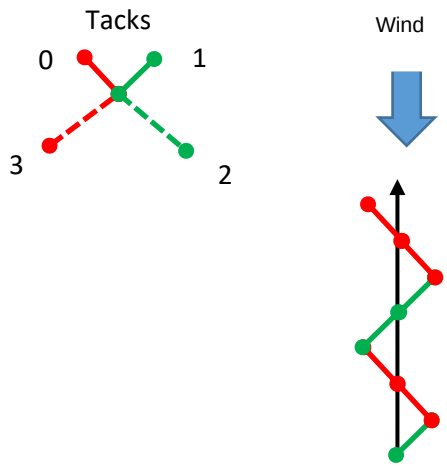


30 min tack interval

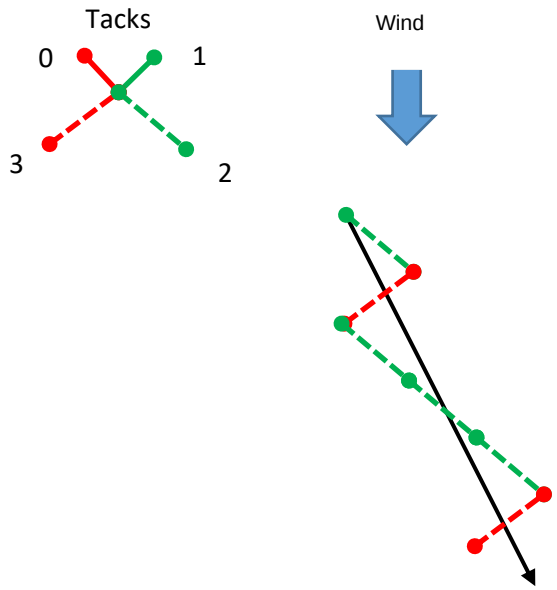
Sailing at different course directions examples

Below are examples on how the autopilot will follow a track.





Tacks: 1001100



Tacks:232223

Autopilot data (Data format 15)

In the autopilot data page, the following columns are displayed.

Parameter name	Description	
Time	Time in UTC. This is the start time for each tack.	Unit
Lat	Latitude in decimal degrees	decimal degrees
Long	Longitude in decimal degrees	decimal degrees
TTFF	Time to first fix. The time in seconds the GPS uses to obtain a valid position.	seconds
Warning	Warning indicator. Indicates that the pilot has to pay attention to the Sailbuoy status.	True/false
Count	Tack counter. For each tack this counter is incremented. It rolls over after a set number of tacks.	Integer
Leak	Leak switch indicator. Indicates a leak in the hull.	True/false
Commands	Received commands count. Shows the number of command values received and processed on the previous transmission.	Integer
I	Current consumption. After GPS fix.	A
V	Battery voltage. Shows the battery voltage. >13.4 fully charged. Maximum voltage is 14.2 volts when charging. 13.0 V ~ 50% charged 12.8 V ~ 15 % charged	V
Temperature	Payload temperature. The internal temperature of the payload electronics.	deg C
Pressure	Payload Pressure. The internal pressure of the payload container.	hPa
Humidity	Payload humidity. The humidity of the payload container. If this value increases, it can indicate a leak in the payload container.	%
TransmissionTries	Iridium transmission tries. Shows the number of transmissions tries on the previous transmission. This is normally set to 3 and if this value is 3 it is due to 3 tries end success or 3 tries and fail.	Integer
OnTimeSec		
Velocity	Velocity over ground. The velocity calculated from the previous GPS position.	m/s
Heading	GPS tack direction. Direction calculated from the previous GPS position.	deg

TrackDistance	Distance from the line defined by the start and end waypoint. If no value (NULL) the distance is greater than 24 km.	m
WaypointDirection	The direction for the current position to the End waypoint.	deg
TrackRadius	The radius of the corridor set by the **$RAD** command	m
WindDirection	Calculated wind direction. The wind direction is calculated based on the behavior of the Sailbuoy on different tacks. The wind direction is recalculated when changing from Tack 0 to 1 or from tack 2 to 3. The autopilot uses this value to calculate the next tack.	deg
AutoModeEnabled	Indicates if the autopilot is controlling the navigation. AutoModeEnabled = 0 if in manual mode	True/false
SwitchWaypointModeEnabled	Is true if fence mode is enabled. Set by the **$SWPMD** command.	True/false
NextAutopilotTack	The next autopilot tack. This is the next tack chosen by the autopilot. When in manual mode this tack will be overridden by the manual tack.	Integer
CurrentTack	The current tack sailed	Integer
PreviousTack, T1, T2, T3	Previous tacks	Integer
WPReached	Waypoint reached	True/false
WithinTrackRadius	Within corridor	True/false
SailAtPortBow	Sail past 90 deg to port count	%
SailAtPort	Sail at port count	%
SailInCentre	Sail middle count	%
SailAtStarboard	Sail at starboard count	%
SailAtStarboardBow	Sail past 90 deg to starboard count	%

Autopilot commands

The Autopilot is configured using the following commands

Command	No Parameters	Description	Default	Min	Max	Example
$TAINT	1	Tack interval in seconds	300	300	3600	$TAINT 1800
$TIMIN	1	Tack interval in minutes	5	5	60	$TIMIN 10
$STRWP	2	Set start waypoint	-			$STRWP 66.54 5.543
$ENDWP	2	End waypoint	-			$ENDWP 67.2 5.55

$RAD	1	Corridor radius in meters	5000	100		$RAD 5000
$AUTO	0	Engage autopilot	On			$AUTO
$TACK	1	Steer tack (disengages autopilot)	-	0	3	$TACK 0
$WPRAD	1	Waypoint reached radius	1000	0		$WPRAD 1000
$SWPMD	1	Enable Fence mode	Off	0	1	$SWPMD 1

$TAINT
Description: Tack interval in seconds
No. of parameters: 1
Parameter type: Integer
Unit: seconds
Minimum parameter value: 300
Maximum parameter value: 3600
Example: $TAINT 900

Sets the tack interval in seconds. $TAINT 1800 will set the tack interval to 30 minutes. This means that every 30 min the autopilot will exit steer tack mode, get new GPS fix and select a new tack. If a short tack interval is set, say $TAINT 300, a new tack will be selected every 5 min. This can affect the performance since it will turn quite often and lose ground in every turn. The best performance is achieved when the tack interval is 30 min.
Most of the power consumption is when the GPS and iridium modems are active, therefore a 5-minute tack interval will use around 6 times as much power as a 30 min. tack interval.
A 5-minute tack interval is useful in manual mode when deploying or retrieving since the position is updated every 5 minutes.
The Tack interval can have the following values: 300,600,900,1800,3600. Other values might lead to unexpected behavior.

$TIMIN
Description: Tack interval in minutes
No. of parameters: 1
Parameter type: Float
Unit: minutes
Minimum parameter value: 5
Maximum parameter value: 60
Example: $TIMIN 10

Sets the tack interval in minutes. This is an alternative to $TAINT but uses minutes instead of seconds. See the $TAINT command.

$STRWP
Description: Start waypoint
No. of parameters: 2
Unit: decimal degrees
Parameter type: Floating point
Minimum parameter value: -180.0
Maximum parameter value: 180.0
Example: $STRWP 65.1232 -5.23423

Sending this parameter sets the start waypoint on the autopilot. The autopilot will use this coordinate to calculate tacks to follow the line defined by start waypoint and end waypoint.

$ENDWP
Description: End waypoint
No. of parameters: 2
Unit: decimal degrees
Parameter type: Floating point
Minimum parameter value: -180.0
Maximum parameter value: 180.0
Example: $ENDWP 65.1232 -5.23423

Sending this parameter sets the end waypoint on the autopilot. The autopilot will use this coordinate to calculate tacks to follow the line defined by start waypoint and end waypoint.
The autopilot will follow the great circle route between the waypoints. The distance between the waypoints can be from 0 meters to thousands of kilometers. It is advisable to send both the start and the end waypoint in the same message or else it is easy to lose track if the autopilot setting.

$RAD
Description: Track radius
No. of parameters: 1
Unit: meters
Parameter type: Integer
Minimum parameter value: 0
Maximum parameter value: -
Example: $RAD 5000

Sending this parameter sets track radius in meters. Sending the command $RAD 5000 will set the track radius to 5 km. The corridor with will then be 10 km. Track radius is the distance the autopilot can veer away from the ideal track. If the autopilot is further away from the ideal track than the track radius, it will only try to get back inside the corridor, ignoring the end waypoint. Once inside the corridor it will resume following the ideal track again.

$AUTO
Description: Engage autopilot
No. of parameters: 0
Unit: -
Parameter type: -
Minimum parameter value: -
Maximum parameter value: -
Example: $AUTO

Sending this command reengages the autopilot after using manual mode. The autopilot will the control the Sailbuoy and select the best tacks to follow the corridoor defined by $STRWP, $ENDWP and $RAD.

$TACK
Description: Steer tack
No. of parameters: 1
Unit: integer
Parameter type: Integer
Minimum parameter value: 0
Maximum parameter value: 3
Example: $TACK 2

Sending this command overrides the autopilot tacks, telling the autopilot to steer a certain tack. For example, sending the command $TACK 2 will tell the autopilot to steer tack 2 indefinitely until a new command is sent.
This way of controlling the autopilot is called manual mode. This mode is mostly used during deployment and retrieval to ensure that the Sailbuoy behaves in a predictable manner. To enter automatic mode again, send the command $AUTO.

$WPRAD
Description: Waypoint reached radius
No. of parameters: 1
Unit: meters
Parameter type: Integer
Minimum parameter value: 0
Maximum parameter value: -
Example: $WPRAD 1000

Sending this command tells the autopilot when the end waypoint is reached. The autopilot only uses this parameter in fence mode. The autopilot checks if its current position is within the circle defined by this radius around the end waypoint. If it is then the end waypoint is reached. For example, sending $WPRAD 2000 will tell the autopilot that the waypoint is reached when the Sailbuoys GPS position is closer than 2 km from the end waypoint. This command is used in fence mode telling the autopilot when to turn around.
Sending the command $WPRAD 0 will tell the autopilot to get as close to the end waypoint as possible before turning around in fence mode. Use $WPRAD 0 unless special requirements are needed.

$SWPMD
Description: Switch waypoint mode (fence mode)
No. of parameters: 1
Unit: integer
Parameter type: Integer
Minimum parameter value: 0
Maximum parameter value: 1
Example: $SWPMD 1

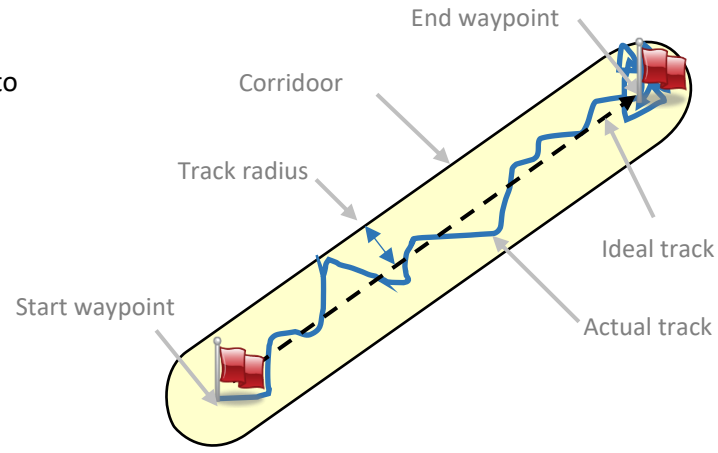
Sending this command tells the autopilot what to do when it reaches the end waypoint (see $WPRAD). If $SWPMD is 0 the autopilot will stay at the end waypoint until further notice (i.e. new commands are sent). If $SWPMD is 1 the autopilot will swap the start and end waypoint causing the Sailbuoy to head back towards the original start waypoint. When it arrives at this new end waypoint, it will swap waypoints again causing it to turn back. It will keep doing this back and forth until told otherwise.

Autopilot modes

Follow track mode
This is the default mode where the Sailbuoy follows an ideal track from its current position to a waypoint.
Commands:
$STRWP
$ENDWP
$RAD

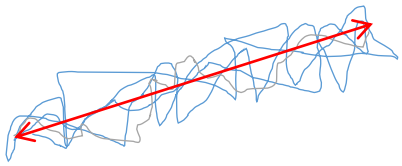
Example:
$STRWP 66.54 5.543
$ENDWP 67.2 5.55
$RAD 5000

Follow a track from N66.54 E5.543 to N67.2 E5.55 with a corridor radius of 5000 meters



Station keeping mode
This mode is default and the Sailbuoy automatically enters this mode when it has reached its end waypoint.

Fence mode
In this mode the Sailbuoy travels between 2 waypoints. When it has reached the end waypoint the current start waypoint becomes the new end waypoint and the current end waypoint becomes to new start waypoint.



Commands:
$SWPMD
$STRWP
$ENDWP
$RAD

Example:
$STRWP 66.54 5.543
$ENDWP 67.2 5.55
$RAD 5000
$SWPMD 1

Manual control

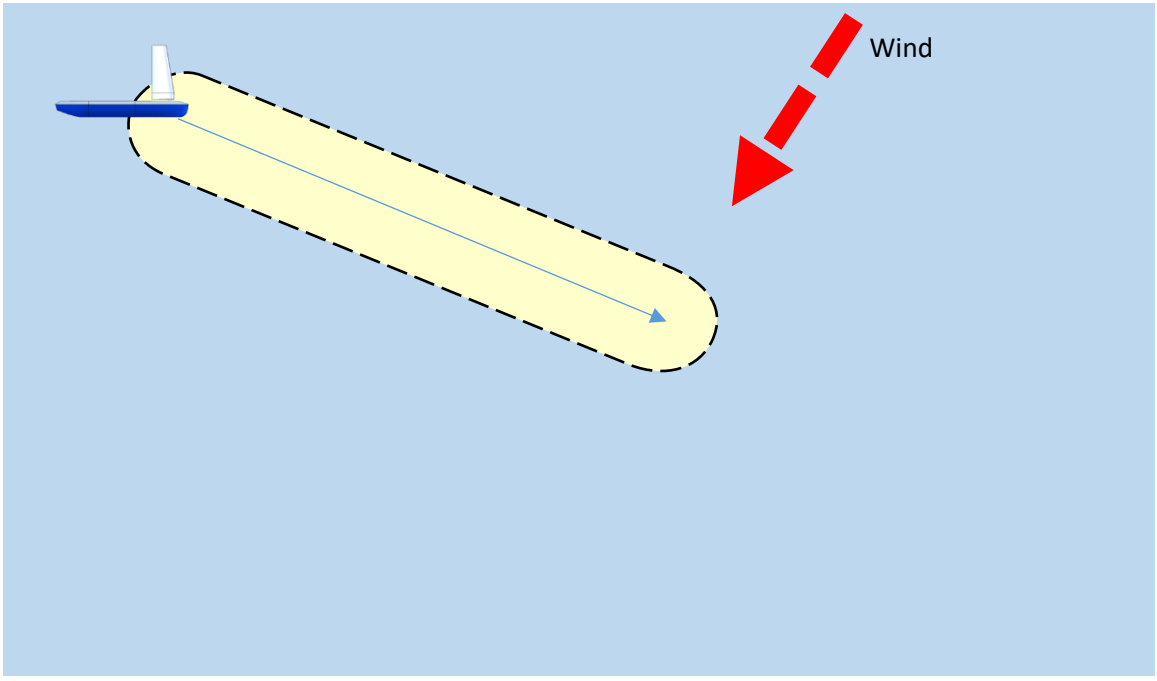
Manual control will override the autopilots next calculated tack.
When the command "$TACK 0" is sent to the autopilot, upon receiving the command it will steer on tack 0 and ignore the tacks calculated by the autopilot. One can send the following commands to steer manually:
$TACK 0
$TACK 1
$TACK 2
$TACK 3

Sending the command $AUTO will end manual mode and revert to the autopilot mode.

Examples.

Go from A to B

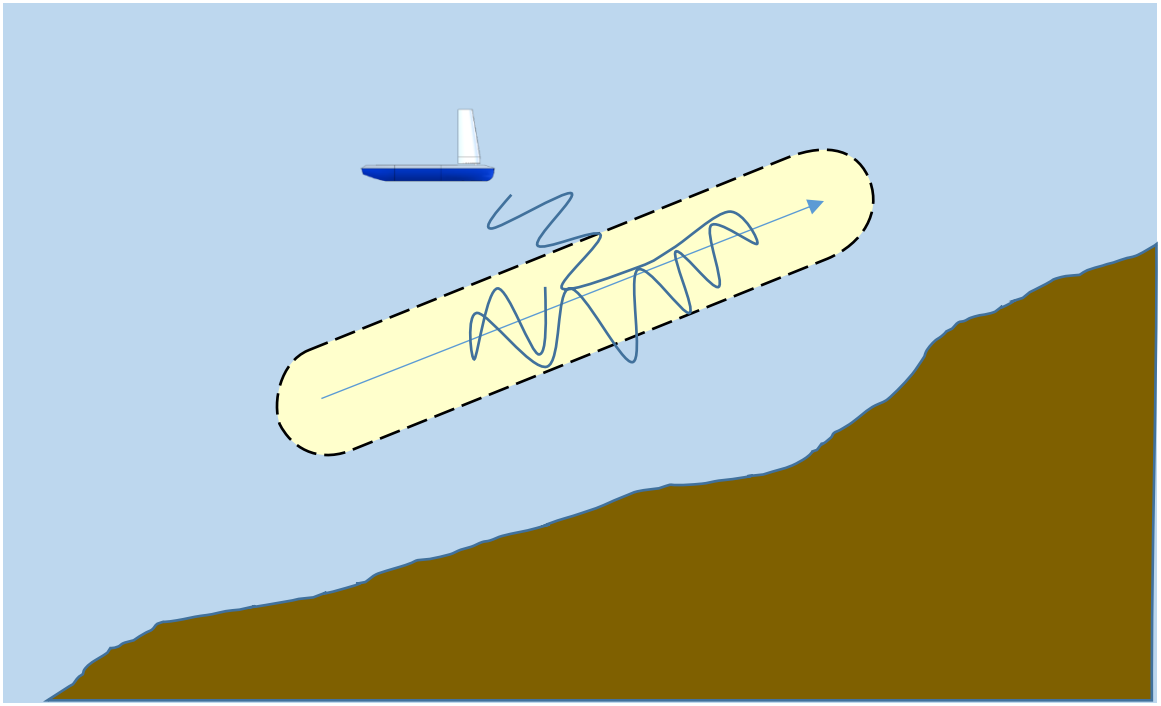
Commands:
$STRWP 66.54 5.543
$ENDWP 67.2 5.55
$RAD 5000



Going close to land

When going close to land, define at track parallel to land.

Commands:
$STRWP 66.54 5.543
$ENDWP 67.2 5.55
$RAD 2000



Setting the Tack interval

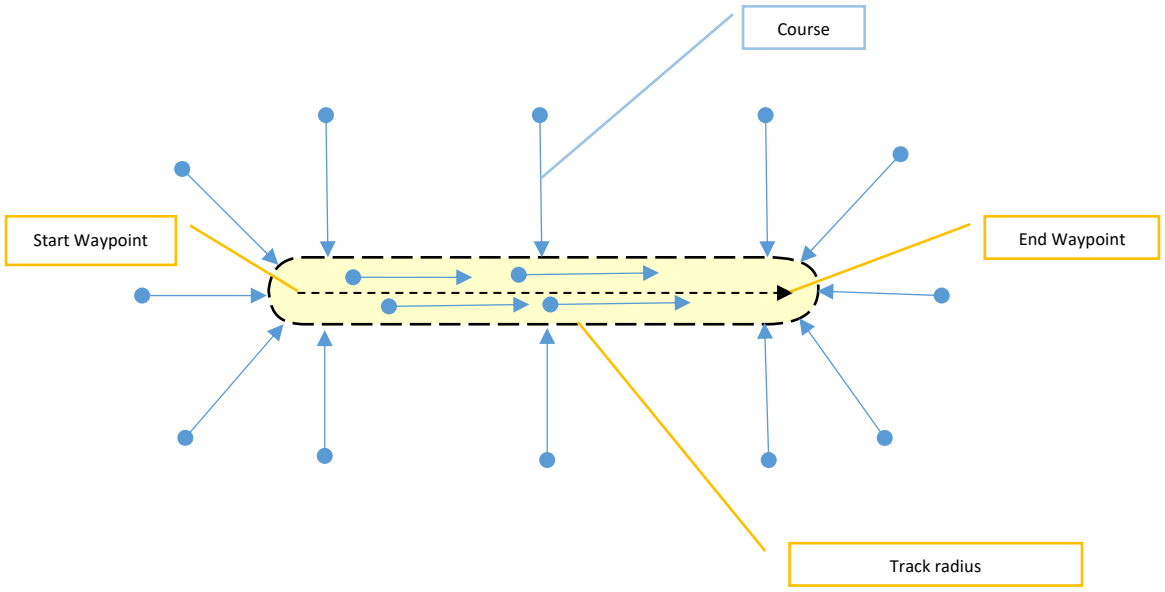
Considerations:

- Turning radius
- Transmission costs
- Power consumption

In practice the tack interval should be set to 15 minutes or above in auto mode but can be reduced to 5 min in manual mode.

Track radius

The track radius defines the corridor width. If the Sailbuoy is further than track radius from the track defined by the start and end waypoints, it will try to get inside the corridor before travelling towards the end waypoint.
When outside of the defined corridor the vehicle will choose a course that is perpendicular to the track.

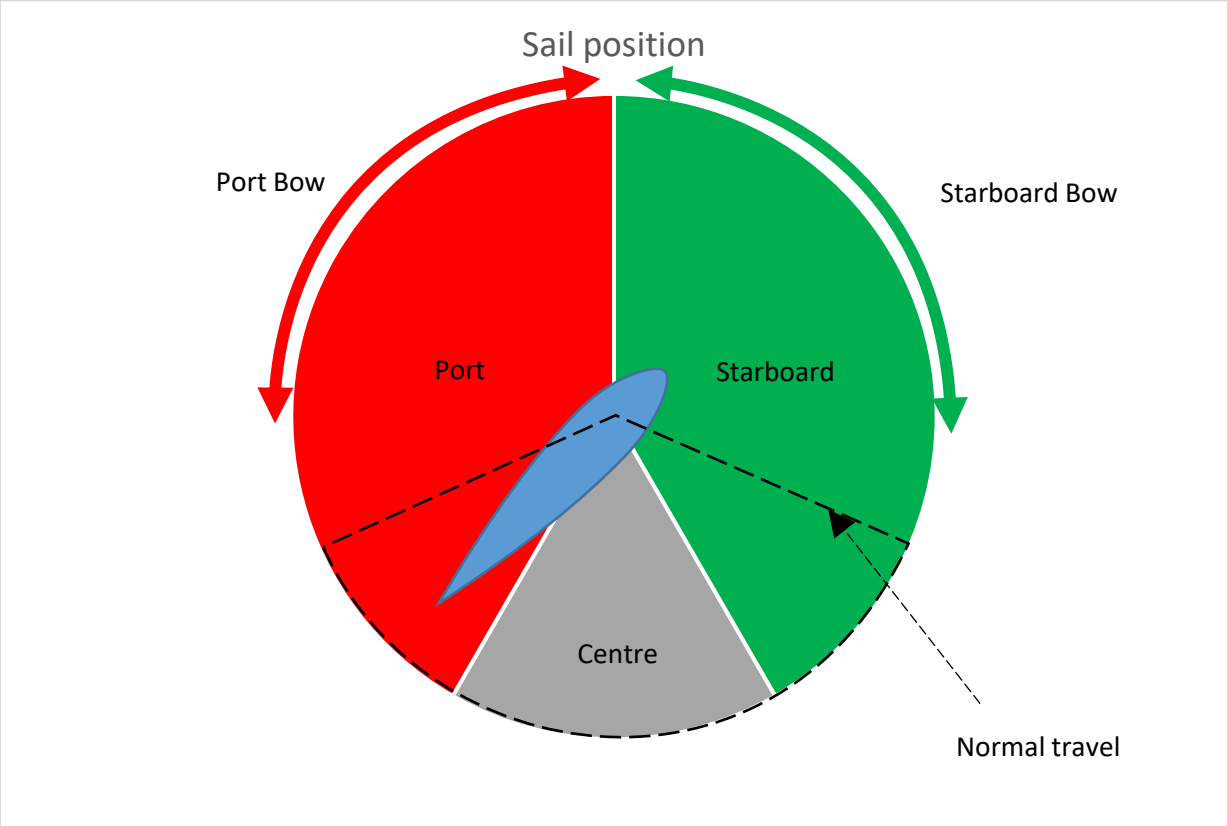


Restarting

The autopilot can be restarted at any point in time without damaging the electronics.

To restart the autopilot first switch it off with the magnetic switch, wait 60 seconds, then remove the magnetic switch to start again.
When restarting the autopilot it will revert back to the default settings.

Understanding Sail Position



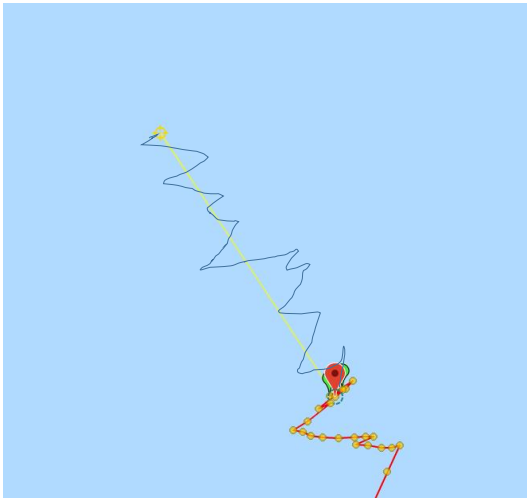
The sail position is included in the message transmitted from the Autopilot. The three values **SailAtPort, SailInCentre** and **SailAtStarboard** show the time spent in each position in percent.
Normally **SailAtPort + SailInCentre + SailAtStarboard = 100%**
The values **SailAtStarboardBow** and **SailAtPortBow** show the time spent int these positions in percent**.**

In normal conditions the sail never moves beyond 45 degrees on each side (**Normal travel**) so **SailAtStarboardBow** and **SailAtPortBow** are zero**.** However, when the wind increases to storm conditions the wind and waves may force the sail outside the normal travel scope and past 90 degrees. In these conditions the Bow positions may be greater than zero.

Piloting examples

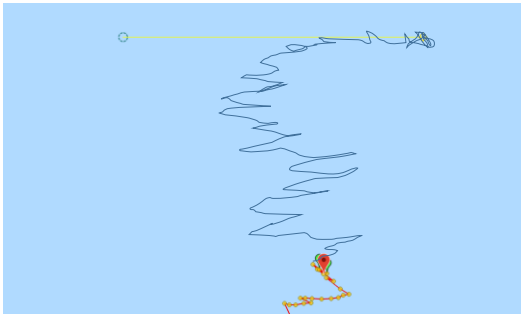
Normal usage

In this case the start waypoint is the current Sailbuoy position. The Sailbuoy will then follow the yellow line according to the track radius to get to the end waypoint. When arriving there it will stay at the end waypoint until a new command is issued.



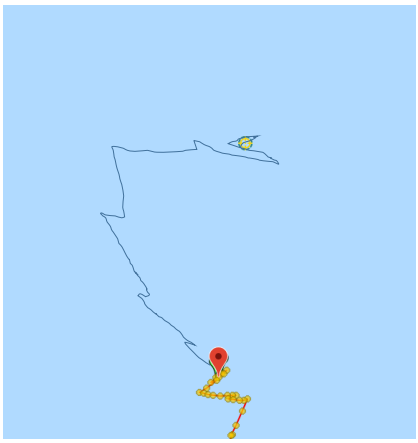
Go to track

Here the start waypoint is not at the current Sailbuoy position. The Sailbuoy will try to get closer to the line, before going to the end waypoint.



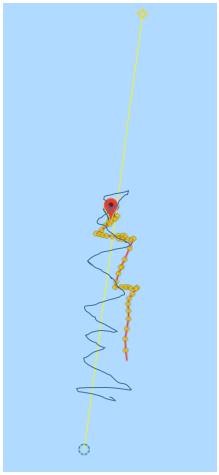
Go to position.

Here the start waypoint and end waypoint are at approximately the same position.
The Sailbuoy will choose the fastest course to get to the waypoint. Here the track radius value has no effect.



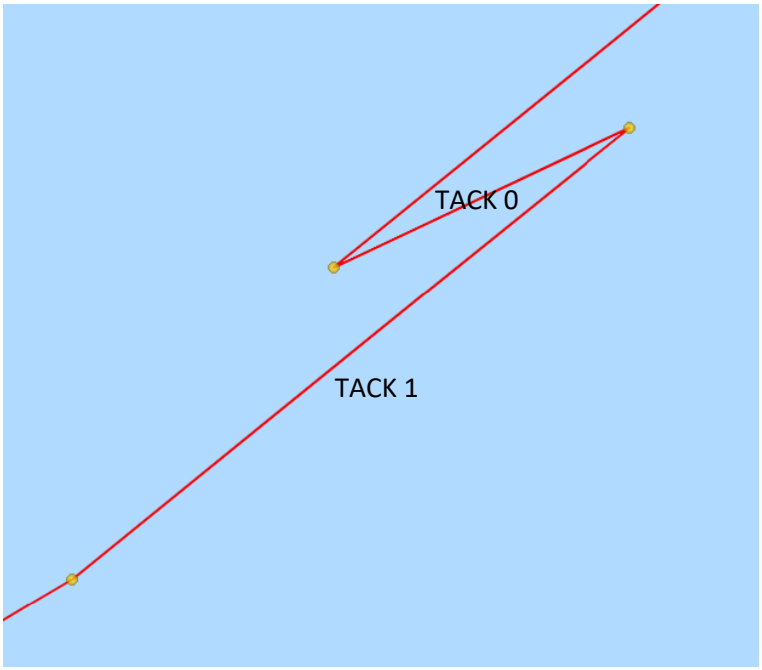
Keep to line

Here the current Sailbuoy position is in the middle of the track and will continue to the end waypoint. However, if the Sailbuoy is pushed backwards it will still try to keep on the defined track.



Determining the surface currents

Since the speed of tack 1 and 0 are the same in the same conditions it is possible to get an idea of the surface currents. The same applies to tack 2 and 3.



Here it is possible to see that since tack 1 is longer than tack 0 there is a current increasing the speed of tack 1 and decreasing the speed of tack 0. It is not possible to accurately determine the direction of the current.