



NAVISUITE KUDA – AUTOPILOT MANUAL

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1 Introduction

The NaviSuite Kuda – Autopilot is a product optimally linking EIVA's NaviSuite Kuda software and a USV. The purpose of this product is to have a universal autopilot that can be installed in all USVs and work with standard NMEA sentences. By using NaviSuite for mission planning, more features and advanced control will be possible. With the autopilot, the user will have full control over the USV either from NaviSuite or via the radio-controlled (RC) NaviSuite Kuda – RC joystick on site.

The NaviSuite Kuda – RC joystick is a rugged handheld controller with buttons, joysticks and a screen for system feedback. A hobby remote from the RC world can be used on request.

NaviSuite Kuda – Autopilot can be configured to fit almost any USV. It can use one or two thrusters and one or two rudders, as well as without a rudder. It works with ESC speed controller (PWM) and with Torqeedo TQ bus motors.

A Power Sense Module from BlueRobotics can be connected to the autopilot to display battery status in NaviSuite Kuda software. Otherwise, if a Torqeedo system is connected, the battery status will automatically be displayed.

The communication between a PC and NaviSuite Kuda – Autopilot can be via Serial (RS232) or Ethernet (UDP).

2 System overview

In the figure below, all key components in contact with the autopilot are shown.

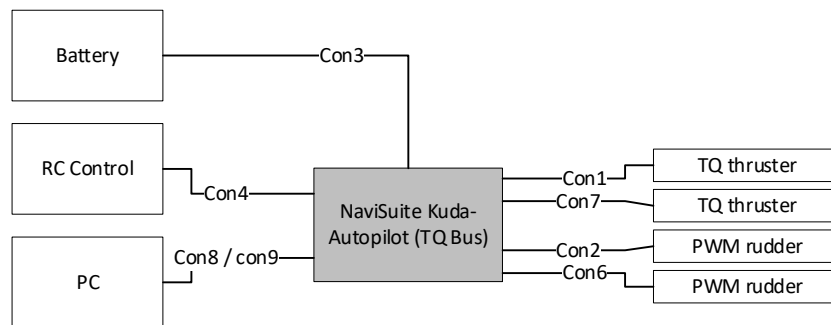


Figure 1 NaviSuite Kuda – Autopilot (TQ Bus) connection overview

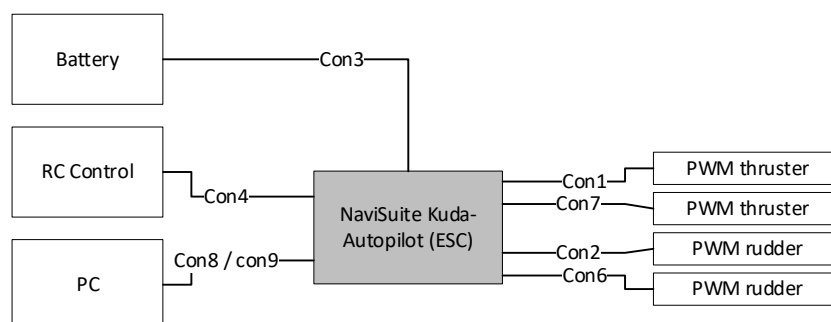


Figure 2 NaviSuite Kuda – Autopilot (ESC) connection overview

2.1 System specification

Parameter	Value	Unit
Input voltage	10-30	V
Power max	30	W
Dimensions	330x133x95	mm
Weight	2.6	kg

3 Installation

3.1 NaviSuite Kuda – Autopilot (TQ bus) Mounting

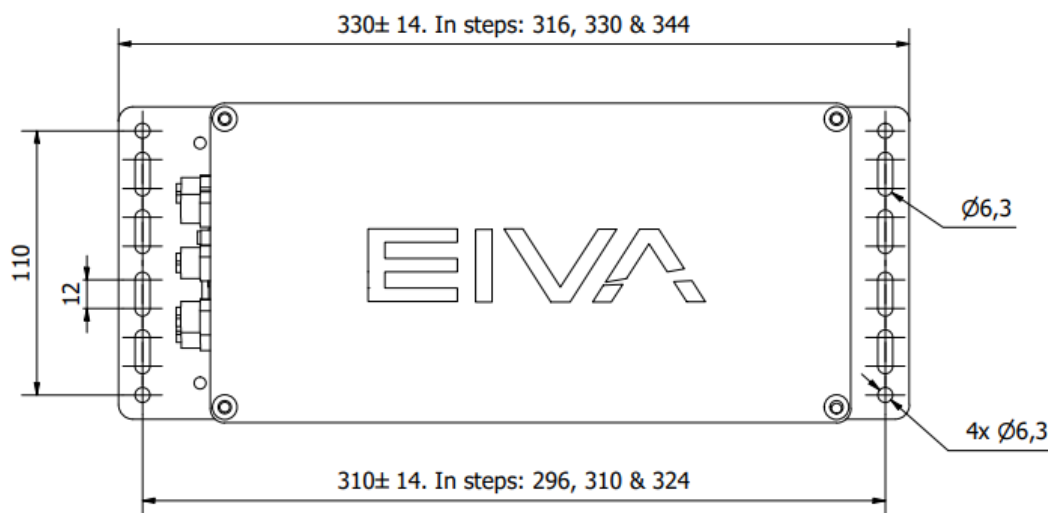


Figure 3 NaviSuite Kuda – Autopilot (TQ bus) top view

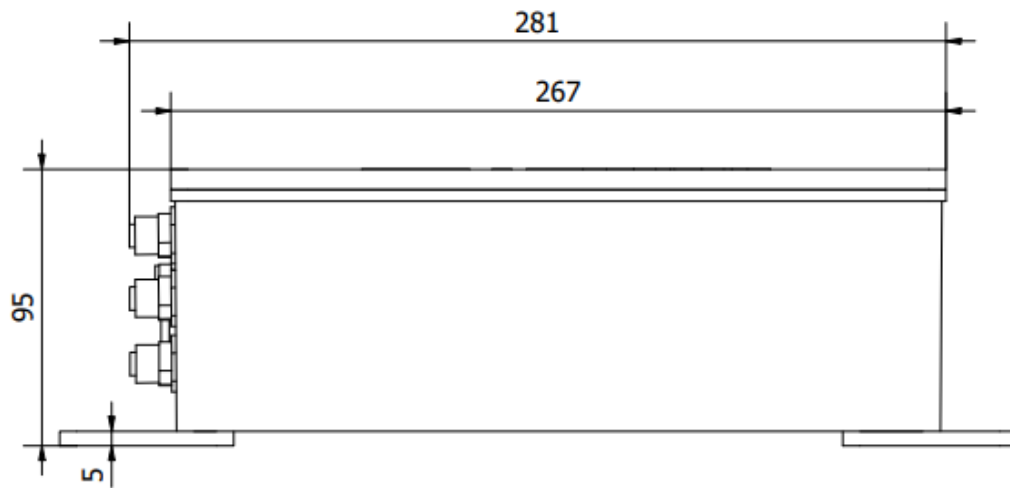


Figure 4 NaviSuite Kuda – Autopilot (TQ bus) side view

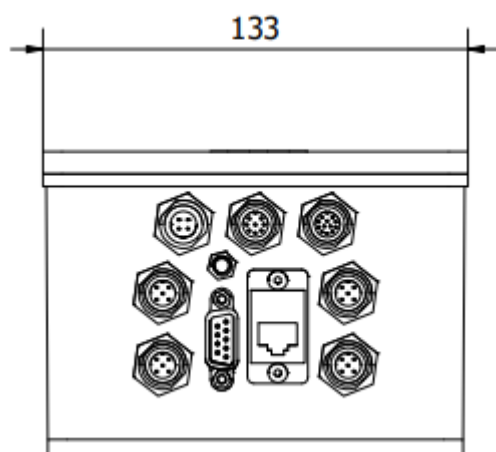


Figure 5 NaviSuite Kuda – Autopilot (TQ bus) flange view

3.2 NaviSuite Kuda – Autopilot (ESC) mounting

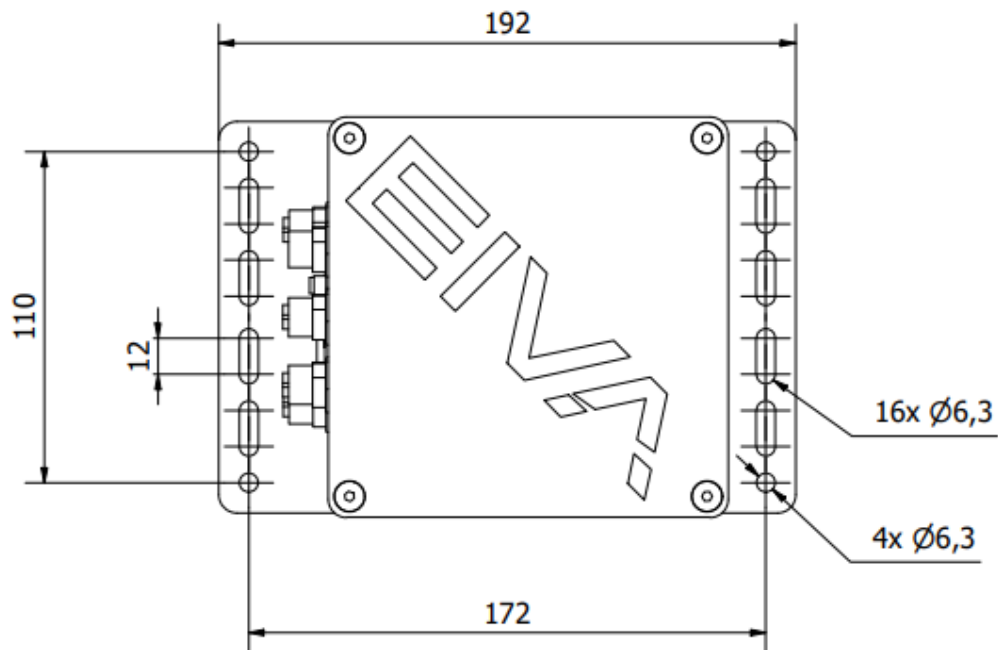


Figure 6 NaviSuite Kuda – Autopilot (ESC) top view

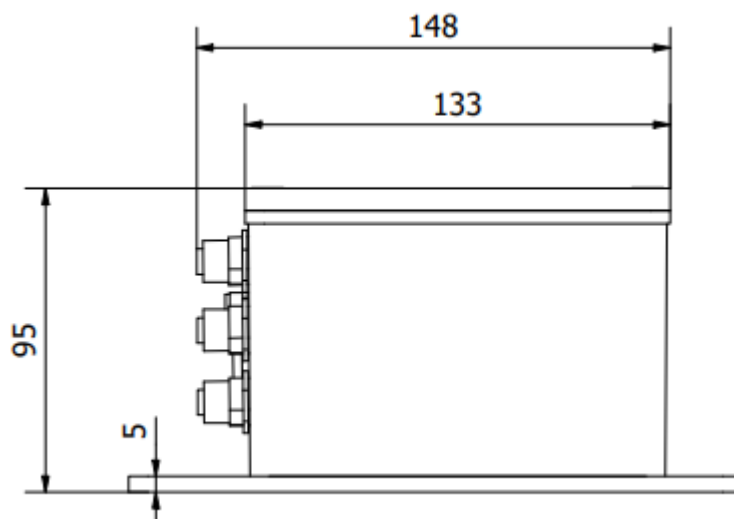


Figure 7 NaviSuite Kuda – Autopilot (ESC) side view

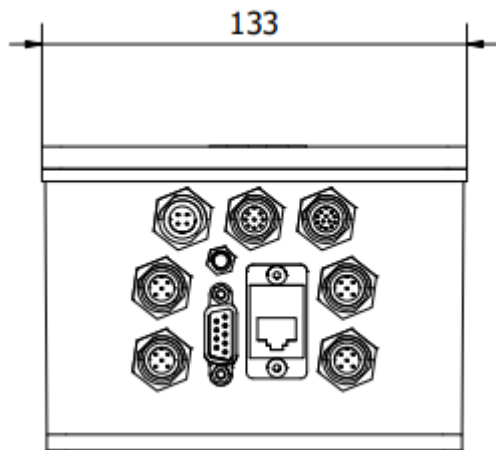


Figure 8 NaviSuite Kuda – Autopilot (ESC) flange view

3.3 Pinout

The pinout will vary depending on configuration.

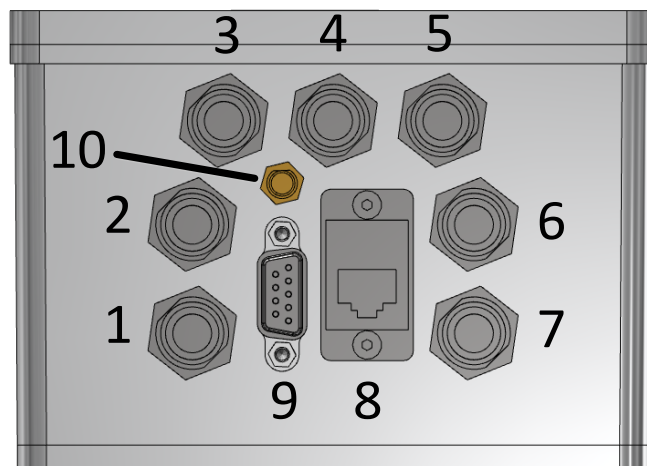


Figure 9 NaviSuite Kuda – Autopilot (ESC) flange

3.3.1 Connector 1 – Starboard thruster

3.3.1.1 Torqeedo setup

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	RS485 D+
3	Torqeedo system switch
4	RS485 D-
5	Torqeedo battery positive

3.3.1.2 ESC setup

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	PWM
3	NC
4	NC
5	NC

3.3.2 Connector 2 – Starboard rudder

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	PWM
3	NC
4	NC
5	NC

3.3.3 Connector 3 – Power IN

Connector type: M12A-04PMMS-SF8001

Pin	Description
1	VIN +9-36VDC (20W)
2	GND
3	NC
4	NC

3.3.4 Connector 4 – LED + RC control

3.3.4.1 RC controller type: SBUS

Connector type: M12A-08PFFS-SF8001

Pin	Description
1	LED battery status. 0–10 V max 1A. Will toggle at 2 Hz when battery charge < 30% and toggle 10 Hz when battery charge <10%.
2	LED thruster enable. 0 V when thruster is disabled and 10 V (max 1 A) when thruster is enabled.
3	Button thruster enable. Pushbutton, when connected to GND thruster enable/disable will toggle.
4	GND
5	NC
6	GND
7	+5 V DC
8	Signal (SBUS)

3.3.4.2 RC controller type: NaviSuite Kuda – RC Joystick

Connector type: M12A-08PFFS-SF8001

Pin	Description
1	LED battery status. 0–10 V max 1 A. Will toggle at 2 Hz when battery charge <30% and toggle 10 Hz when battery charge <10%.
2	LED thruster enable. 0 V when thruster is disabled and 10 V (max 1 A) when thruster is enabled.
3	Button thruster enable. Pushbutton, when connected to GND thruster enable/disable will toggle.
4	GND
5	CAN L
6	GND
7	+12 V DC
8	CAN H

3.3.5 Connector 5 – Battery measure

Works with BlueRobotics PSM-ASM-R3-RP.

Connector type: M12A-12PFFS-SF8001

Pin	Description
1	NC
2	Battery 1 current
3	Battery 1 voltage
4	GND
5	NC
6	Battery 2 current
7	Battery 2 voltage
8	GND
9	NC
10	Battery 3 current
11	Battery 3 voltage
12	GND

3.3.6 Connector 6 – Port rudder

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	PWM
3	NC
4	NC
5	NC

3.3.7 Connector 7 – Port thruster

3.3.7.1 Torqeedo setup

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	RS485 D+
3	Torqeedo system switch
4	RS485 D-
5	Torqeedo battery positive

3.3.7.2 PWM speed controller

Connector type: M12A-05PFFS-SF8001

Pin	Description
1	GND
2	PWM
3	NC
4	NC
5	NC

3.3.8 Connector 8 – Ethernet port

Connector type: RJ45

Pin	Description
1	10 / 100 Mbit

3.3.9 Connector 9 – Serial RS232

Connector type: DB9 female

Pin	Description
1	NC
2	TX
3	RX
4	NC
5	GND
6	NC
7	NC
8	NC
9	NC

3.3.10 Connector 10 – SMA connector

Connector type: SMA

Pin	Description
1	NC

4 Setup

After installing NaviSuite Kuda – Autopilot hardware, it needs to be configured to fit the USV.

The thruster and rudder setup must be defined. Default is two thrusters and two rudders. This will give the best handling.

When the USV setup is defined and in water, it needs to be tuned before it can sail autonomously.

4.1 NaviSuite Kuda – Autopilot communication

Communication can be via ethernet(UDP) or serial. The data rate must be 10 Hz.
Ethernet data from PC to autopilot: UDP on IP:192.168.2.11 PORT:8877 (data from autopilot to PC is on PORT:8878).
Serial: RS232 baud rate 115200.

4.2 PC communication

Minimum requirement is NMEA HDT and APB.
To hold a constant speed VTG and APB is required.

All setup commands can be transmitted to the autopilot at any time and are transmitted via the same ETH or Serial as NMEA strings.

4.3 USV setup

All the physical limits of the USV must be defined in NaviSuite Kuda – Autopilot to have the best control of the USV.

All values are set with series of commands that must be transmitted to NaviSuite Kuda – Autopilot via Serial or UDP.

4.3.1 Thruster setup

The NaviSuite Kuda – Autopilot supports one or two thrusters. If configured for two thrusters, they will be controlled using vector steering.

Supported thruster types are PWM speed controllers and Torqeedo TQ Bus systems.

Command for one thruster setup: \$EIVA,USV,THR,THR,SET,1,

Command for two thrusters setup: \$EIVA,USV,THR,THR,SET,2,

4.3.2 Speed vs turn blend

When controlling a USV with vector steering, the user can specify if the USV shall prioritize to hold the speed when turning, or if the speed may be compromised to have a better turn radius.

This setting will first have an effect when one thruster is used 100%.

This value describes how many percentages may the speed be compromised when turning.

If the value is 100% then the USV can give full throttle forward on one thruster and full throttle reverse on the other thruster, meaning the USV will lose forward momentum, but will be able to make sharp turns.

If the value is 0% then the forward speed will always be held. The turn radius will then be increased.

Command to set value: \$EIVA,USV,THR,BLD,SET,[value],
[value] must be 0 to 100.

4.3.3 Rudder setup

The NaviSuite Kuda – Autopilot supports one or two rudders, as well as no rudders.

The rudders are expected to turn the thruster.

Command for one rudder setup: \$EIVA,USV,THR,RUD,SET,1,

Command for two rudders setup: \$EIVA,USV,THR,RUD,SET,2,

4.3.4 USV handling ability

All USVs behave differently, so to get the best control and accuracy the autopilot needs to know how the USV is behaving. This is expressed by one number that can easily be measured and input into the NaviSuite Kuda – Autopilot. To calculate it, follow this measurement procedure:

1. Sail in manual mode at a speed of 1 m/s
2. At some point, turn the USV as hard as it can

3. Note where the USV is starting to turn (the red line in Figure 7)
4. When the USV has turned 90 degrees, stop the test and measure the distance it took to make the turn. This length is the value which you will input.

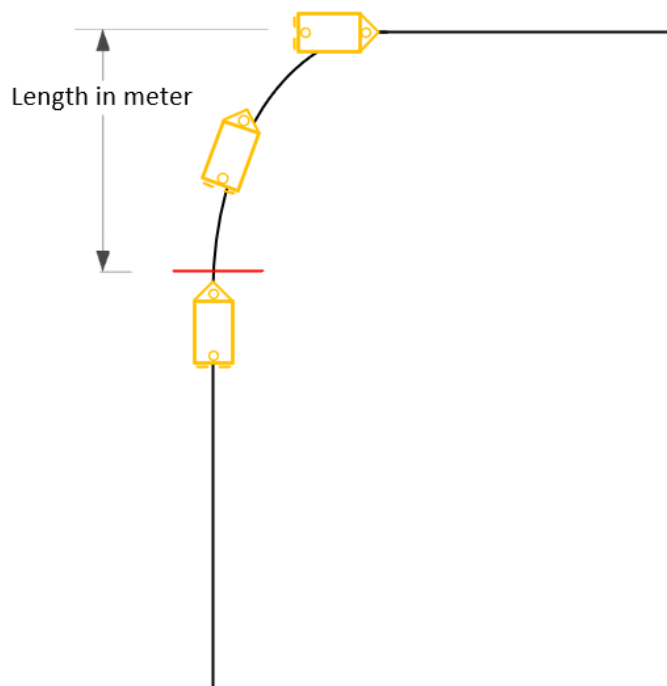


Figure 10 USV handling ability measurement procedure

The command to set this value: `$EIVA,USV,AGL,SET,"[Value]"`,

[value] must be a float between 0 and 100.

4.4 System tuning

Multiple PID loops are constantly running to control the USV. One PID loop is helping the path algorithm to calculate the right direction for the USV. Another PID loop is controlling the USV heading, and the last configurable PID loop is controlling the USV speed.

The PID are tuned to the correct value through trial and error.

4.4.1 Tuning procedure

The PID settings can be changed at any time, and new values will be used immediately.

The first PID loop to tune is the heading PID. This can be done by using operation mode **Manual with heading assist**. Sail with different speeds when tuning.

\$EIVA,USV,PID,HP,SET,"Value",
EX: \$EIVA,USV,PID,HP,SET,2.1,

\$EIVA,USV,PID,HI,SET,"Value",
EX: \$EIVA,USV,PID,HI,SET,1.1,

\$EIVA,USV,PID,HD,SET,"Value",
EX: \$EIVA,USV,PID,HD,SET,1.6,

When the USV can hold its heading without it being too aggressive, then move on and tune the path PID. Start with making a straight runline and make it follow it. When it does that, then put a turn on, and change the radius of the turn.

\$EIVA,USV,PID,PP,SET,"Value",
EX: \$EIVA,USV,PID,PP,SET,0.3,

\$EIVA,USV,PID,PI,SET,"Value",
EX: \$EIVA,USV,PID,PI,SET,0.5,

\$EIVA,USV,PID,PD,SET,"Value",
EX: \$EIVA,USV,PID,PD,SET,0.2,

The speed PID is used in operation mode **Auto**. The thing to look for is how fast the USV can achieve a new speed.

\$EIVA,USV,PID,SP,SET,"Value",
EX: \$EIVA,USV,PID,SP,SET,0.5,

\$EIVA,USV,PID,SI,SET,"Value",
EX: \$EIVA,USV,PID,SI,SET,0.8,

\$EIVA,USV,PID,SD,SET,"Value",
EX: \$EIVA,USV,PID,SD,SET,0.3,

4.5 RC joystick

4.5.1 NaviSuite Kuda – RC Joystick

The NaviSuite Kuda – RC Joystick will come as a joystick controller, a receiver and an antenna. The antenna must be mounted in line-of-sight of the joystick.

On the NaviSuite Kuda – RC Joystick controller are two joysticks, four switches on the front and four buttons on the sides. Each of these are linked to a channel:

Input	Description	Channel
Joystick up/down left side	Moving the stick up will drive the USV forward. Moving it down will reverse	0
Joystick right/left left side		1
Joystick up/down right side	Not used	-
Joystick right/left right side	Moving the stick right will turn the USV towards starboard. Moving the stick left will turn the USV towards port.	2
Switch top front	Change operation mode Top -> Full manual Middle -> Manual with heading assist Bottom -> Auto	7
Switch mid front		8
Switch bottom left front	In modes Full manual and Manual with heading assist the user must specify if the USV is controlled from the NaviSuite Kuda – RC Joystick or from a joystick connected to the PC.	6
Switch bottom right front	The thrusters and rudders can be enabled and disabled. At boot up, they are disabled.	5
Button top left side (C1)		9
Button bottom left side (C2)	Not used	-
Button top right side (C3)		10
Button bottom right side (C4)		11



Figure 11 NaviSuite Kuda – RC Joystick

To use the NaviSuite Kuda – RC Joystick, follow these steps:

1. Turn on NaviSuite Kuda – Autopilot
2. Turn on NaviSuite Kuda – RC Joystick by releasing the emergency button on the side
3. Press and hold buttons C3 and C4
4. Release when NaviSuite Kuda – RC Joystick starts to vibrate
 - a. If connection to the receiver cannot be established, then the NaviSuite Kuda – RC Joystick will continue to vibrate

5 Operation

5.1 Operation modes

5.1.1 Idle

When booting the NaviSuite Kuda – Autopilot, it will start in **Idle** mode. All input will be ignored, and thrusters and rudders will be set to neutral position.

5.1.2 Full manual

In **Full Manual** mode, the USV is controlled fully from manual input via NaviSuite Kuda – RC Joystick or a joystick connected to the PC. In this mode, the user input will be executed immediately with limited filtering.

5.1.3 Manual with heading assist

Manual with heading assist mode is the same as **Full manual** with the only exception that the autopilot will lock the heading to a user-set value.

The target heading will be set from the remote controller, the same joystick that turns the USV in **Full manual**. When entering this mode, the autopilot will try to hold current heading.

5.1.4 Auto

In **Auto** mode, the NaviSuite Kuda – Autopilot will control the USV only from NMEA strings describing a runline. All other user input is ignored.

The autopilot will aim to hold a fixed speed based on thruster speed. Default is 30%, where 100% is max speed thrusters can deliver.

The autopilot will automatically change between **Loiter** mode and **Follow runline** mode.

5.2 System failure modes

There are different system failure modes. These modes can be triggered at all times (except when in operation mode **Idle**). The user can choose which system failure mode will be triggered if something goes wrong.

In **Full manual**, 1 second without any input will trigger system failure.

In **Manual with heading assist**, 1 second without any manual input or 1 second without USV heading will trigger system failure.

In **Auto** mode, 2 seconds without the necessary input will trigger system failure.

5.2.1 Wait

In this system failure mode, thrusters and rudders will be set to neutral position and wait until new data comes in, then continue.

5.2.2 Continue

In this system failure mode, the autopilot will continue to sail with the last received data.

5.2.3 Do 180

In this system failure mode, the USV will make a 180 degree turn and sail straight to where it came from.