



SP Technical Research Institute of Sweden



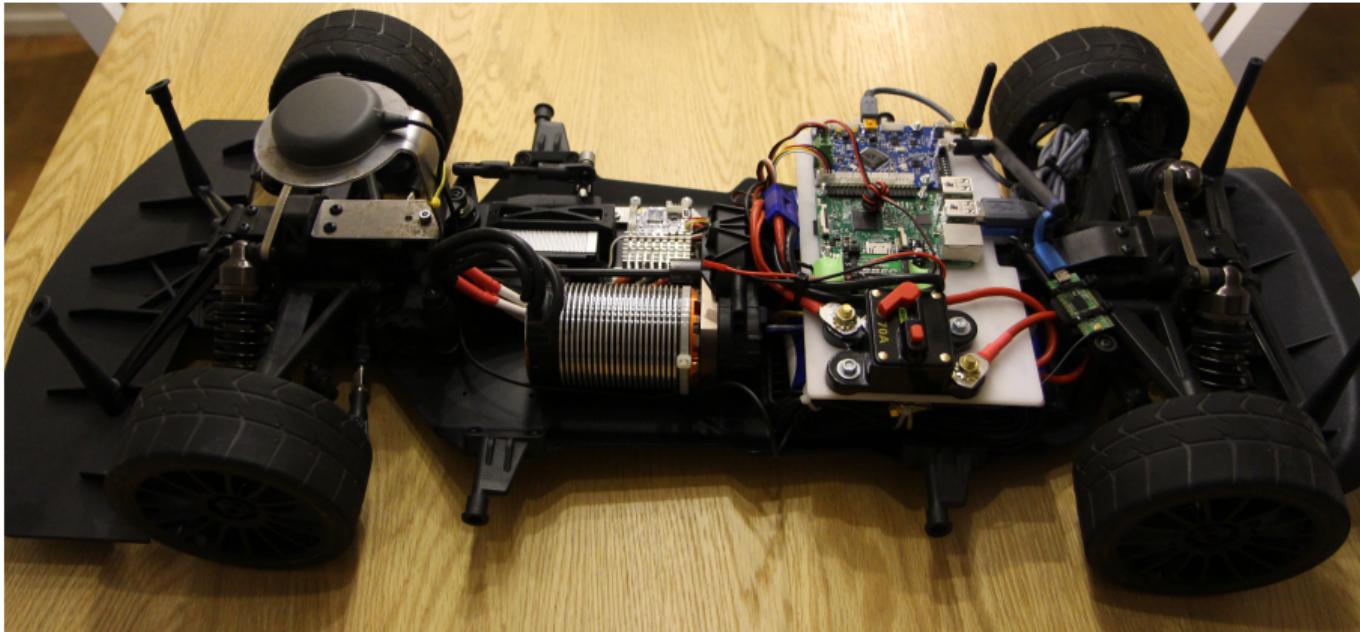
The SP RC Car

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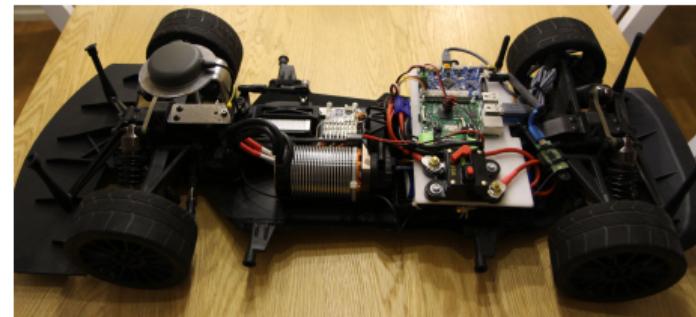
2016-07-06, Darmstadt

The SP RC Car



The SP RC Car Overview

- Positioning:
 - IMU (Accelerometer, Gyroscope, Magnetometer).
 - RTK GPS.
 - Odometry.
- Speed from <1 Km/h to 80 Km/h
- Autopilot.
- Custom user interface.
 - Visualization, remote control, configuration, communication.
 - RTK correction data from different possible sources.
- Fully open source.

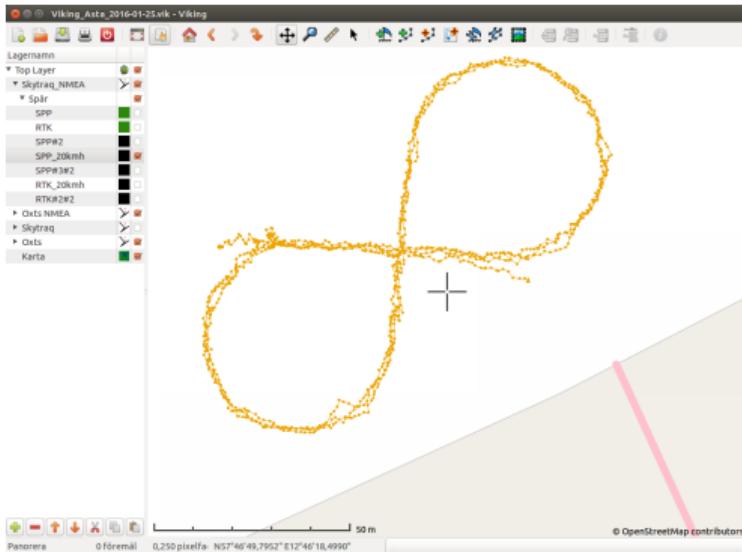




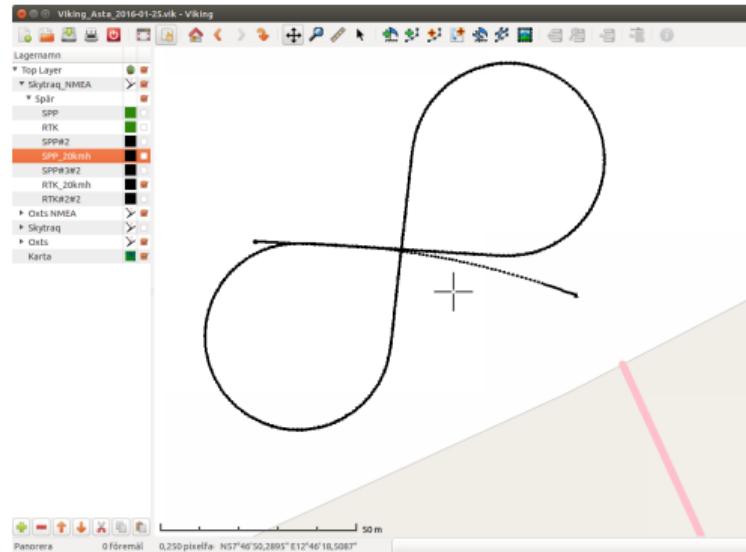
The SP RC Car

RTK GPS for accurate positioning

SPP



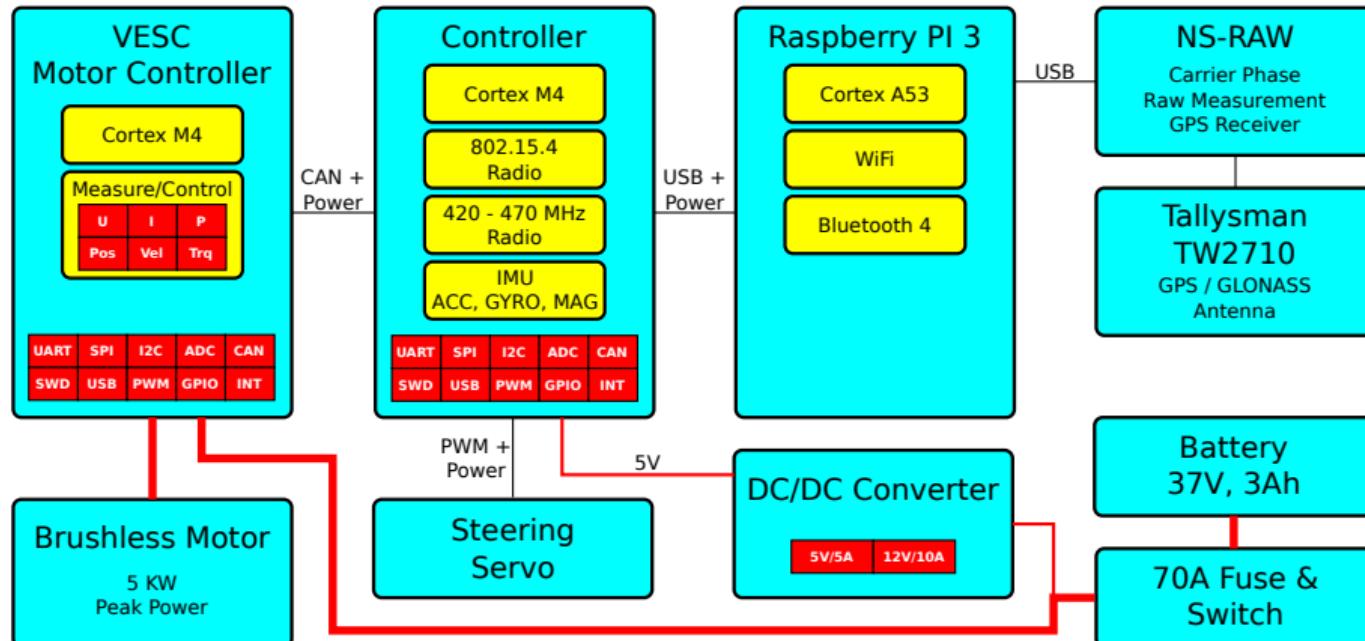
RTK





The SP RC Car

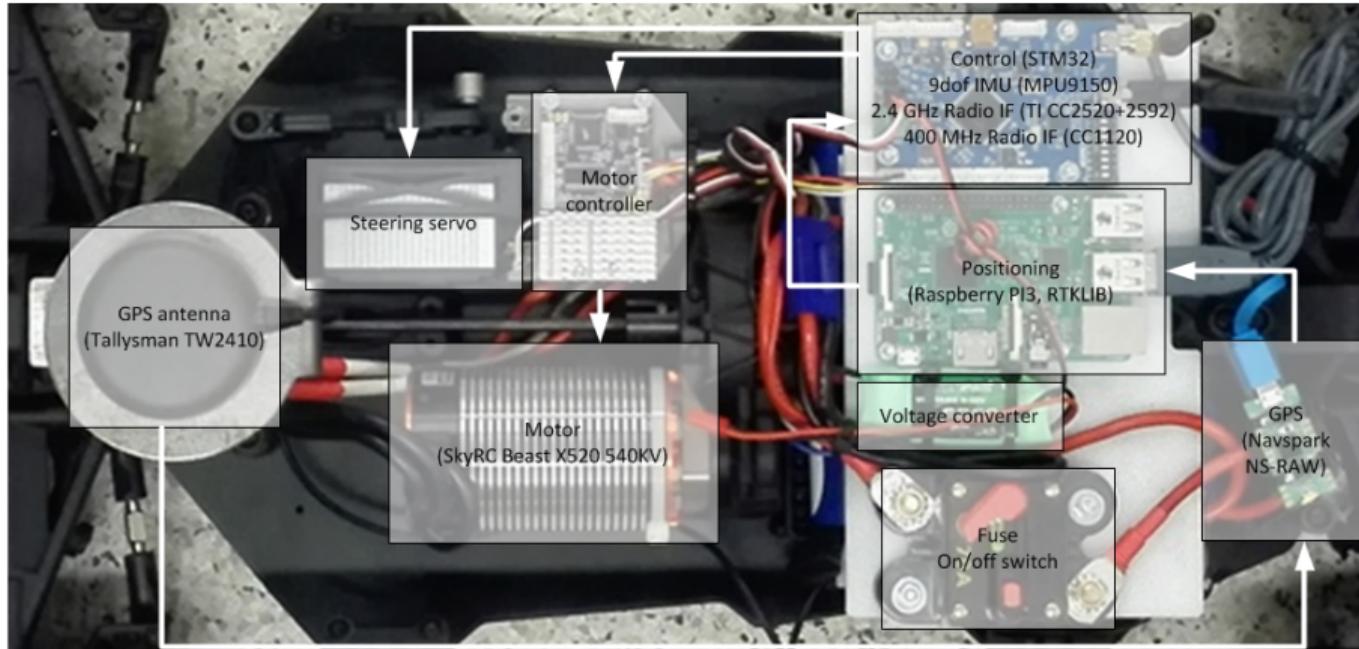
Hardware Block Diagram





The SP RC Car

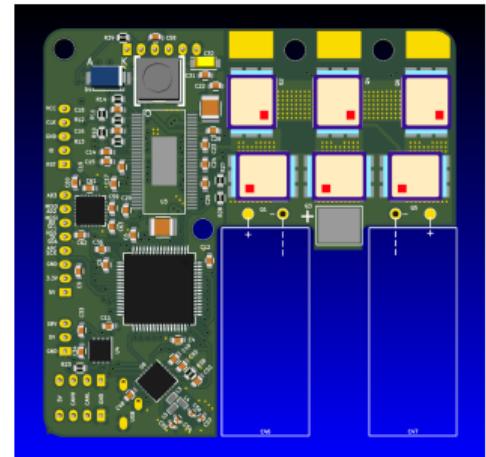
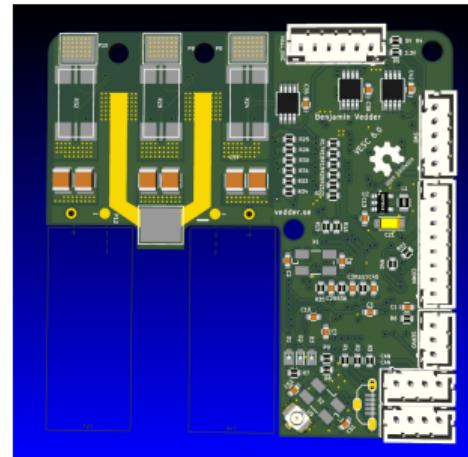
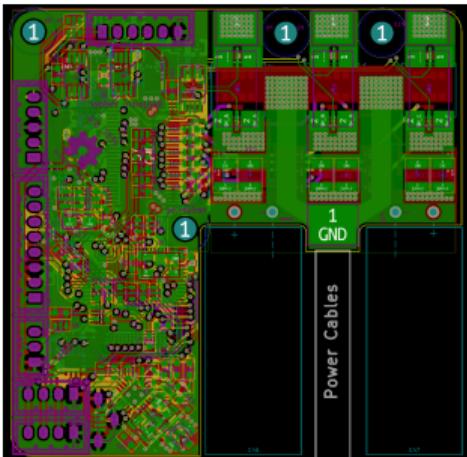
Hardware Locations





The SP RC Car VESC Motor Controller

- Benjamins open source and open hardware spare time project developed during the past 4 years.
- 20 000+ lines of C code in 100+ files.
- 14 threads + interrupts and DMA.
- Cont power: 2000W
- Peak power: over 5000W
- Size: 40mm x 60mm and 40g weight.





The SP RC Car

VESC - BLDC Tool GUI

BLDC Tool

Motor Configuration App Configuration Realtime Data BEMF Plot Current Plot Terminal Firmware Rotor Position Experiment

General

Sensor Mode: Encoder Hall Sensorless

Current Control: $K_p: 0,0036$ $K_i: 5,05$

Encoder: $Ofs: 180,00$ $Rat: 7,00$

Sensorless ERPM: $2500,00$ Invert Encoder

F_SW and DTc: $F_{SW}: 20000 \text{ Hz}$ $DTc: 0,080 \mu\text{s}$

Speed Tracker: $Kp: 2000,00$ $Ki: 20000,00$

Duty Downramp: $Kp: 10,00$ $Ki: 200,00$

Openloop RPM: $600,00 \text{ RPM}$

Motor Parameters (for the sensorless observer)

$R: 0,00505 \Omega$ $L: 3,58 \mu\text{H}$ $\lambda: 0,003544$

Observer Gain (x1M): $200,99$

Hall Sensors

Table: 255 255 255 255 255 255 255 255

Detect and Calculate Parameters

Measure R and L: $R: 0,00000 \Omega$ $L: 0,00 \mu\text{H}$ $\lambda: 0,00000000$

Measure λ (Req: R): $I: 6,00 \text{ A}$ $Duty: 0,50$ $RPM: 700,0$ ← To spin up for λ

Calc CC (Req: R and L): $TC: 1000,0 \mu\text{s}$ $Kp: 0,0000$ $Ki: 0,00$

Detect Encoder

Measure: $I: 15,00 \text{ A}$ $Ofs: 0,00$ $Rat: 0,00$ Invert Encoder

Detect Hall Sensors

Measure: $I: 15,00 \text{ A}$ 0 0 0 0 0 0 0 0

Serial Connection

ttyS4

UDP Connection

0 CAN Fwd

Control **Plot and Sample**

Control

0,20
15000
3,0 A
3,0 A
0,000
 KB Ctrl $I: 3,0 \text{ A}$

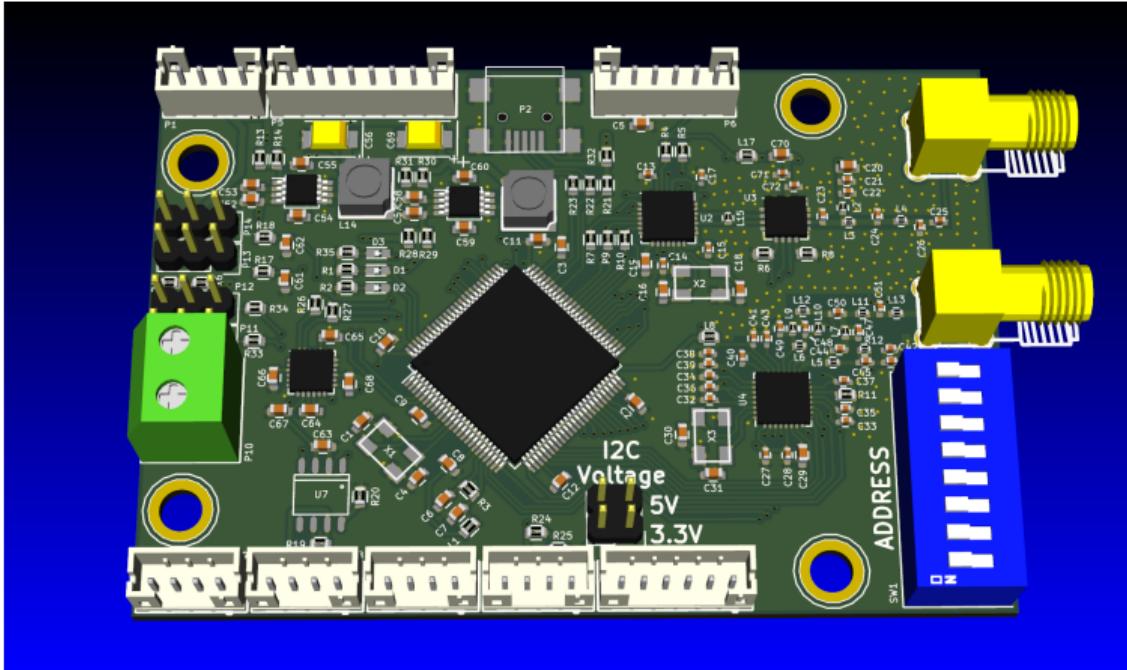
Release Motor (ESC)

Not connected



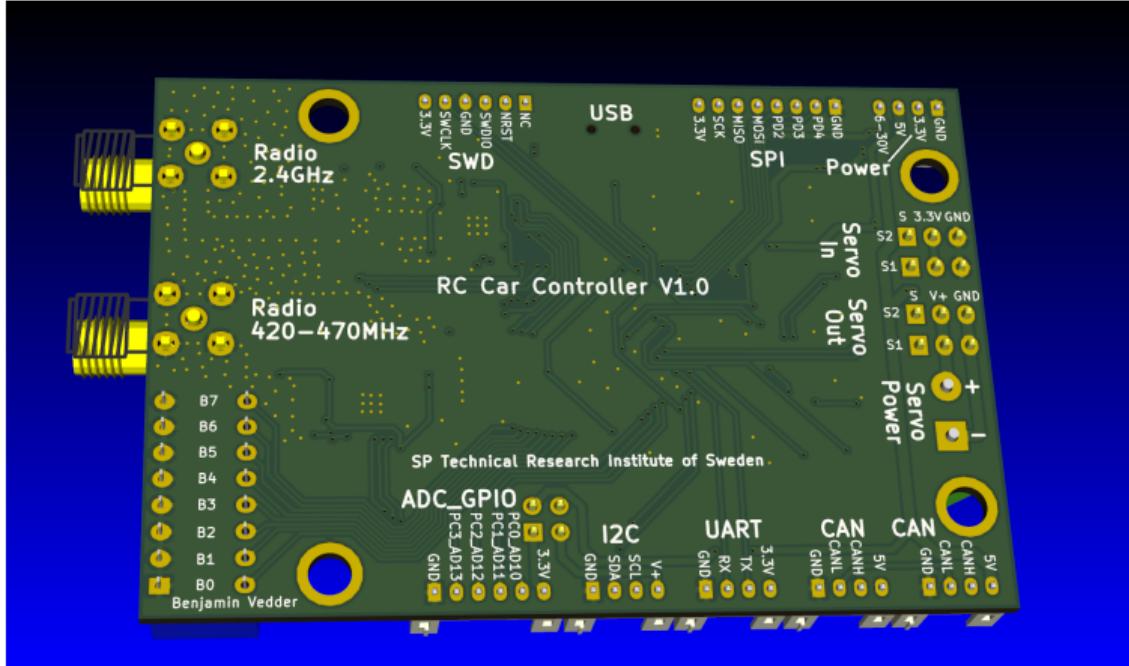
The SP RC Car

Main Controller - front





The SP RC Car Controller - back





The SP RC Car RC Car Tool - Main Page



RC Car Tool

Cars

Car 0

RTCM Client Map

Car 0

Car ID: 0

Poll Data

Keyboard Control

AutoPilot

Update Route from Map

Clear Route

Serial Connection

IF - /dev/ttyACM3

Refresh Connect

UDP Connection

Disconnect

Cars

Remove Car Add Car

Joystick

/dev/input/js0 Not connected

Disconnect Connect

Control

Mode: Duty Current

Max: 0,15

Throttle: 0% G: 0,030

Steering: 0% G: 0,080

Orientation IMU Terminal Calibration GPS Configuration

FW 1.0 Battery: 51,3 % (38,10 V) MOSFET Temp: 30°C

FAULT_CODE_NONE

BLDC Tool UDP Server

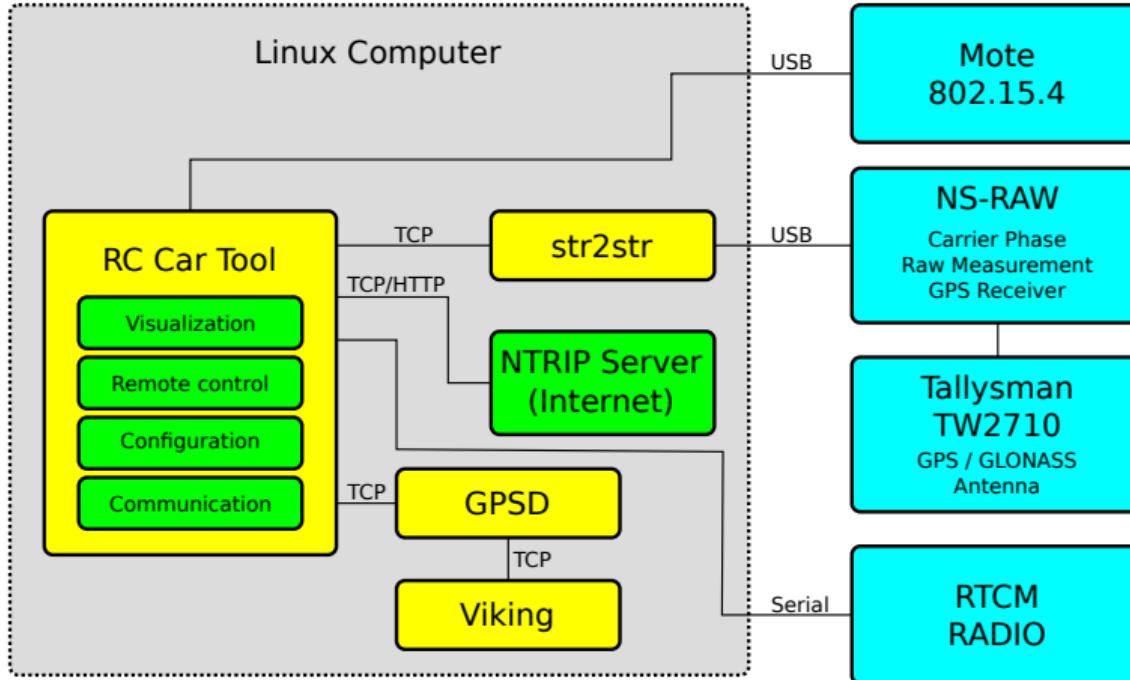
Not connected

This screenshot shows the main interface of the RC Car Tool. It features a central window displaying a 3D model of a red toy car. Below the car are four horizontal bars representing sensor data: Roll (0°), Pitch (-1°), Yaw (-169°), and Speed (0.00 km/h). At the bottom of this window are tabs for Orientation, IMU, Terminal, Calibration, GPS, and Configuration, with Orientation currently selected. A status bar at the very bottom shows FW 1.0, a battery level of 51,3 % (38,10 V), and a MOSFET Temp of 30°C. The status bar also includes a green FAULT_CODE_NONE indicator and a checkbox for BLDC Tool UDP Server. To the left of the main window is a vertical sidebar with tabs for Cars, RTCM Client, and Map. The Cars tab is active, showing 'Car 0'. On the right side of the interface are several connection panels: Serial Connection (IF - /dev/ttyACM3, Refresh, Connect), UDP Connection (Disconnect), Cars (Remove Car, Add Car), Joystick (/dev/input/js0, Not connected, Disconnect, Connect), and Control (Mode: Duty, Current, Max: 0,15, Throttle: 0%, G: 0,030, Steering: 0%, G: 0,080). A decorative graphic of colored squares is located in the top right corner.



The SP RC Car

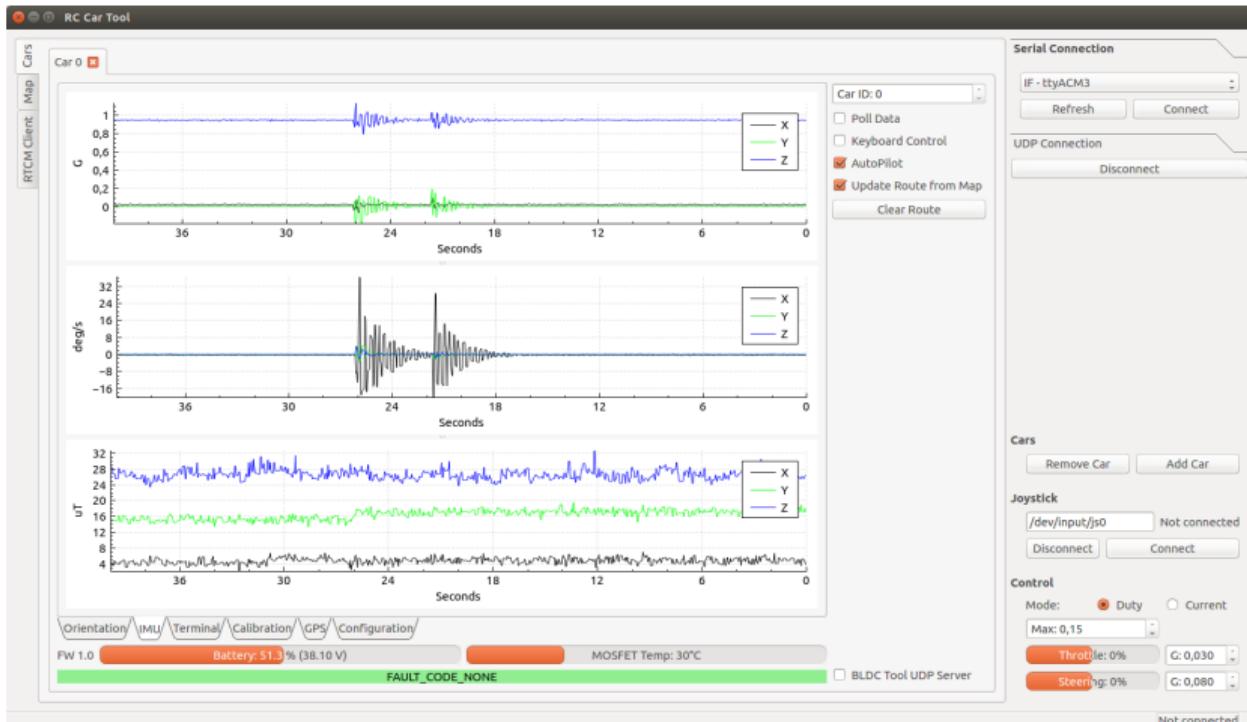
Linux Computer Block Diagram





The SP RC Car

RC Car Tool - IMU raw data





The SP RC Car RC Car Tool - Terminal

RC Car Tool

Cars

Car 0

addr	stack	prio	refs	state	name	time
200010e8	20000764	64	1	SLEEPING	main	148
20001138	20001124	1	1	READY	idle	9988795
20001500	20001174	2	1	SUSPENDED	usb_lld pump	4668
20007290	200074dc	64	1	QUEUED	USB-Serial read	26588
20006ef8	20007214	64	1	WTOREVT	USB-Serial write	8
20005560	2000667c	64	1	WTOREVT	USB-Serial process	16215
20009f68	2000b0cc	64	1	SLEEPING	Servo ramp	8
20004270	20004a9c	65	1	SUSPENDED	MPU Sampling	1133009
20001788	20001ca4	66	1	WTOREVT	CC2520 EXTI	6834
20001db8	20001fb4	64	1	SLEEPING	CC2520 EXC	85
20003448	2000393c	64	1	CURRENT	CC2520 RX	488
20003ed9	200041ec	64	1	WTOREVT	CC2520 TX	22160
2000a538	2000a7ec	65	1	WTOREVT	CAN read	15810
200086f0	200097c4	64	1	READY	CAN process	38424
2000c908	2000cb74	64	1	SLEEPING	Autopilot	23

Valid commands are:

```
help
Show this help
ping
Print pong here to see if the reply works
mem
Show memory usage
threads
List all threads
vesc
Forward command to VESC
```

Orientation IMU Terminal Calibration GPS Configuration

FW 1.0 Battery: 51.3 % (38.10 V) MOSFET Temp: 30°C FAULT_CODE_NONE

Serial Connection

IF - /dev/ttyACM3

Car ID: 0

Poll Data

Keyboard Control

AutoPilot

Update Route from Map

Clear Route

UDP Connection

Disconnect

Cars

Remove Car Add Car

Joystick

/dev/input/js0 Not connected

Disconnect Connect

Control

Mode: Duty Current

Max: 0,15

Throttle: 0% G: 0,030

Steering: 0% G: 0,080

BLDC Tool UDP Server

Not connected



The SP RC Car RC Car Tool - GPS Data

RC Car Tool

Cars Map RTCM Client

Car 0

NMEA TCP Server Log to File

Port: 27910 Activate log_nmea.txt Choose... Activate

\$GPRMC,110325,30,A,5742.9886989,N,01253.5043005,E,4.47,12.29,150416,0.0,E,A*0B
\$GPGGA,110325,30,5742.9886989,N,01253.5043005,E,1,04,1.0,268.345,M,35.026,M,0.0,*4D

\$GPGSA,A,3,15,18,24,30,,*,3.6,2,3,2,8,1*29
\$GPGSV,1,1,04,15,61,271,21,18,26,308,38,24,26,265,37,30,23,085,27,1*64

\$GPRMC,110325,40,A,5742.9893408,N,01253.5052139,E,1.37,12.29,150416,0.0,E,A*00
\$GPGGA,110325,40,5742.9893408,N,01253.5052139,E,1,04,1.0,262.036,M,35.026,M,0.0,*49

\$GPGSA,A,3,15,18,24,30,,*,3.6,2,3,2,8,1*29
\$GPGSV,1,1,04,15,61,271,21,18,26,308,38,24,26,265,37,30,23,085,27,1*64

\$GPRMC,110325,50,A,5742.9891378,N,01253.5062437,E,7.43,7.69,150416,0.0,E,A*3E
\$GPGGA,110325,50,5742.9891378,N,01253.5062437,E,1,04,1.0,247.435,M,35.026,M,0.0,*42

\$GPGSA,A,3,15,18,24,30,,*,3.6,2,3,2,8,1*29
\$GPGSV,1,1,04,15,61,271,21,18,26,308,38,24,26,265,37,30,23,085,27,1*64

\$GPGSA,A,1,,*,*1E
\$GPGSV,1,1,0,,*,*49

\$GPGSA,A,1,,*,*1E
\$GPGSV,1,1,0,,*,*49

\$GPGSA,A,1,,*,*1E
\$GPGSV,1,1,0,,*,*49

Orientation IMU Terminal Calibration GPS Configuration

Clear

FW 1.0 Battery: 51.3 % (38.10 V) MOSFET Temp: 30°C FAULT_CODE_NONE BLDC Tool UDP Server

Serial Connection

IF - /dev/ttyACM3 Refresh Connect

UDP Connection Disconnect

Cars Remove Car Add Car

Joystick /dev/input/js0 Not connected Disconnect Connect

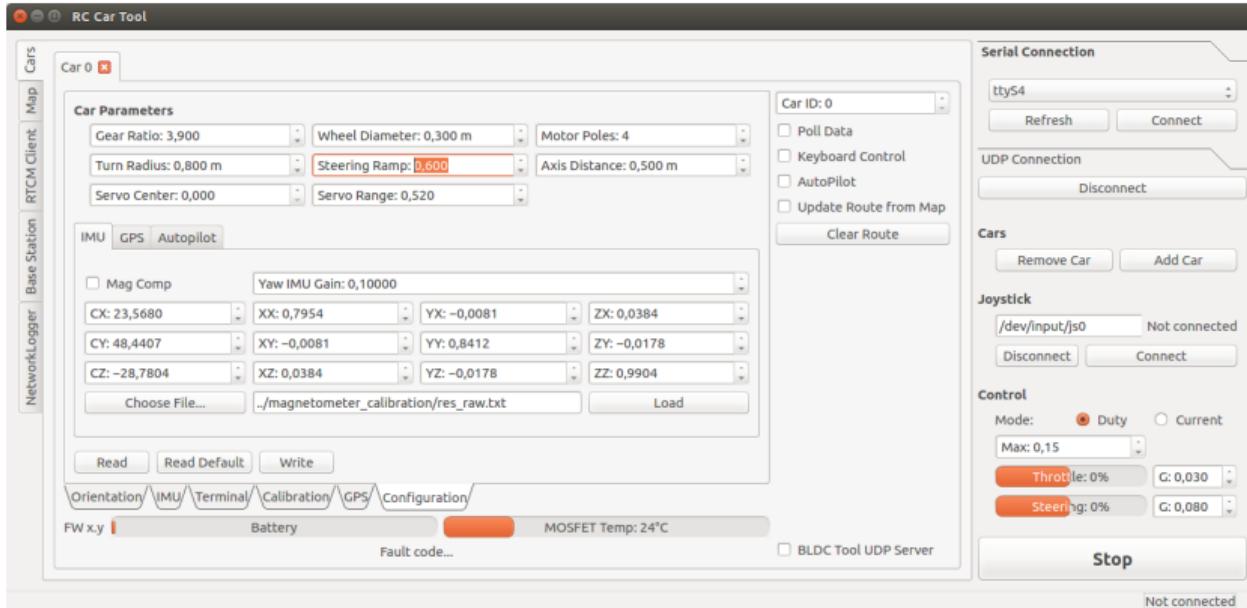
Control Mode: Duty Current Max: 0,15 Throttle: 0% G: 0,030 Steering: 0% G: 0,080

Not connected

A screenshot of the RC Car Tool software. The main window displays a log of NMEA GPS data. On the left, there's a navigation bar with tabs for Cars, Map, RTCM Client, and a selected tab for RTCM Client. The central area shows the log of GPS data with various sentences like \$GPRMC, \$GPGGA, and \$GPGSA. Below the log are tabs for Orientation, IMU, Terminal, Calibration, GPS, and Configuration. At the bottom, there are status indicators for Firmware version (FW 1.0), battery level (51.3%), and MOSFET temperature (30°C). A green bar at the bottom indicates no fault codes. On the right side, there are three main sections: Serial Connection (with a dropdown for IF and buttons for Refresh and Connect), UDP Connection (with a Disconnect button), and Control (with tabs for Mode (Duty or Current), Max value (0,15), and sliders for Throttle and Steering with their respective G values). A 'Cars' section with Remove Car and Add Car buttons is also present.

The SP RC Car

RC Car Tool - Configuration





The SP RC Car

RC Car Tool - RTCM correction data

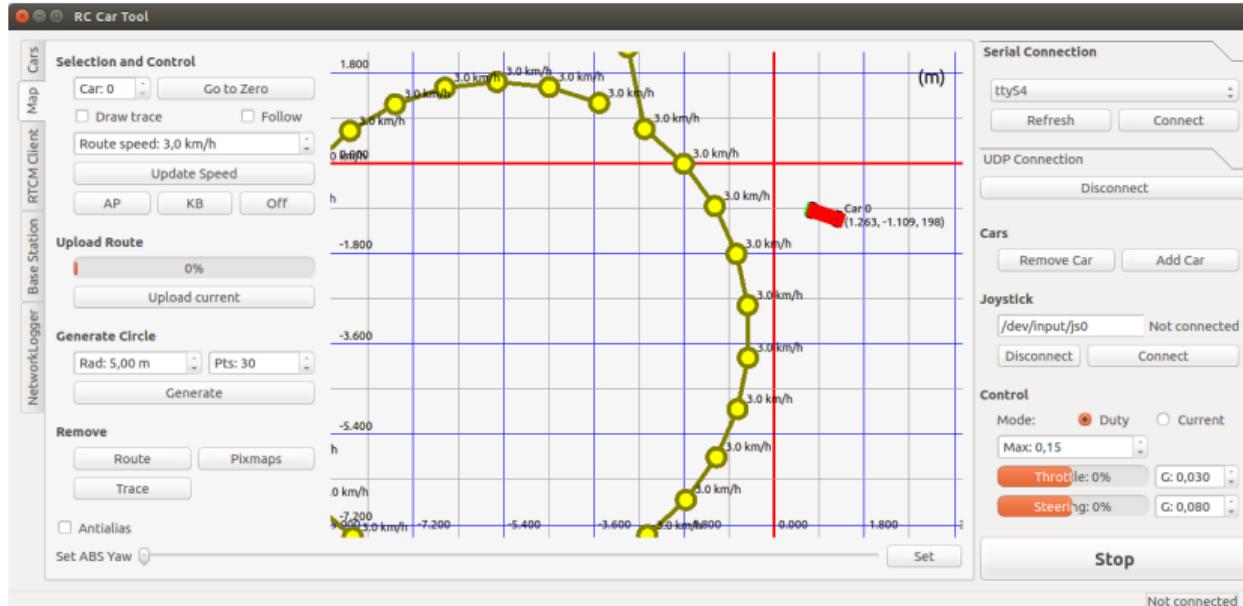
The screenshot shows the "RC Car Tool" application window. The left sidebar has tabs for "TCP / NTRIP", "Cars", "Map", and "RTCM Client". The main area contains:

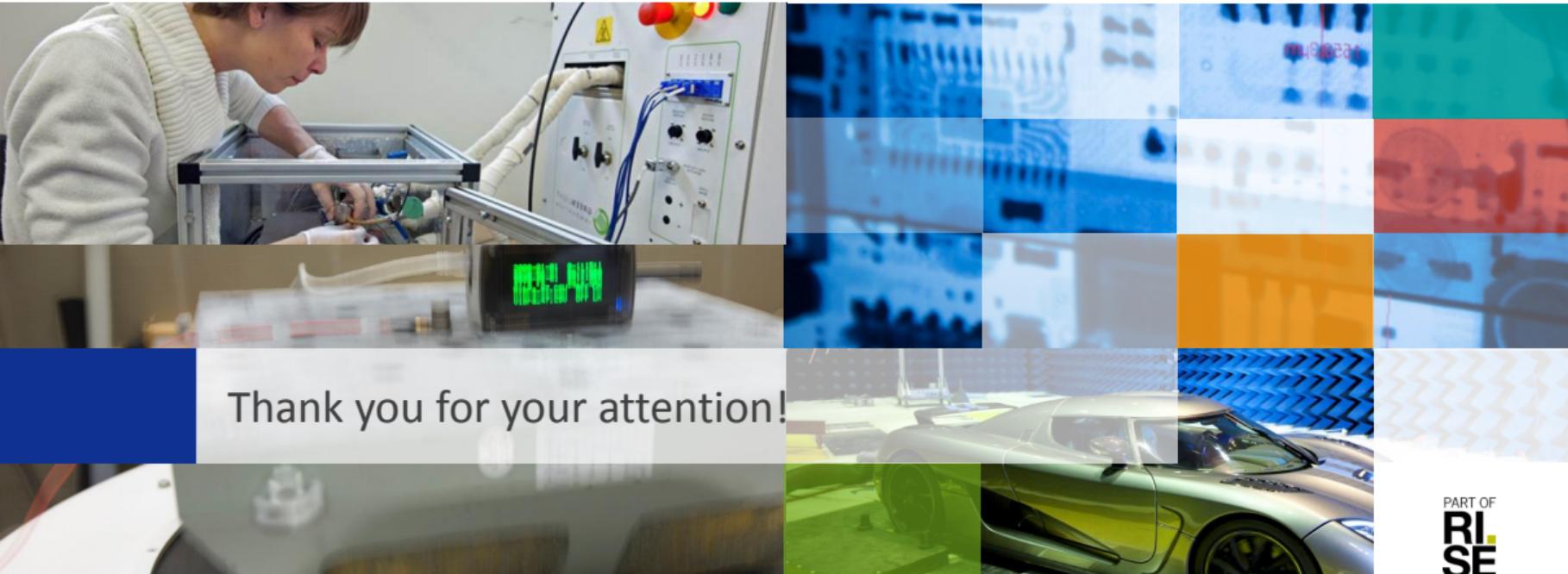
- TCP / NTRIP:** Server set to "localhost", Port 65300, Stream SPT00. Buttons for "Not connected", "Disconnect", and "Connect".
- Serial:** Refresh button, port "ttyS4", baud rate "115200". Buttons for "Not Connected", "Disconnect", and "Connect".
- Received RTCM Messages:** GPS Observations (1001, 1002, 1003, 1004, 1005), GLONASS Observations (1009, 1010, 1006, 1019, 1011, 1012, 1020). A "Reset All" button is at the bottom.
- Last Ref Position:** Latitude 57,71495867, Longitude 12,89134921, Altitude h: 219,000, Ant h: 0,000. A checkbox for "Send (or override) Reference Station Position" is checked.
- Serial Connection:** Interface set to "IF - ttyACM3", "Refresh", "Connect".
- UDP Connection:** "Disconnect" button.
- Cars:** "Remove Car", "Add Car" buttons.
- Joystick:** Interface set to "/dev/input/js0", "Not connected", "Disconnect", "Connect".
- Control:** Mode: Duty (radio button selected), Current (radio button unselected), Max: 0,15. Throttle: 0%, G: 0,030. Steering: 0%, G: 0,080.
- Status:** "Not connected" message at the bottom right.



The SP RC Car

RC Car Tool - Real-time plot and track editor for the autopilot





Thank you for your attention!