CONTENTS

ABBREVIATIONS

DNF	Did Not Finish
DV	Driverless Vehicle
EBS	Emergency Brake System
FMEA	Failure Modes and Effects Analysis
FSG	Formula Student Germany
NMT	Network Management Protocol (CANopen)
PDO	Process Data Object (CANopen)
RES	Remote Emergency System
SDO	Service Data Object (CANopen)

DT FSG Driverless Vehicle (DV) Technical Specifications 2017

DT 1 Document Purpose

DT 1.0.1 The intention of this document is to introduce various competition-specific procedures and technical details. These can be seen as clarification on the Formula Student Rules 2017 and will be handled as such.

DT 1.0.2 First, the technical devices specific for Formula Student Germany (FSG) are introduced including brief summaries on installation, configuration and handling. The following chapter deepens the description of the track layout section of the rules (D 4.3, D 5.1, D 8.1) by naming used cone hardware and markings and giving example setup figures. Finally, processes of the static and dynamic events are described for better understanding.

DT 1.0.3 This document may receive continuous updates and the described content will be subject of changes until the competition itself. In doubt, the content of the Formula Student Rules will be the basis for decisions.

DT 2 Technical Systems

DT 2.1 Remote Emergency System

DT 2.1.1 The Remote Emergency System (RES) that has to be used for the competition is a GF2000i-codec/T53R98 combination from Gross-Funk GmbH[1].

- SIL3 (EN61508) certified
- EMV certified
- communication in 430 MHz to 440 MHz band
- 12 V to 24 V supply voltage (0.26 A @12 V)
- 450 g, 173 mm × 113 mm × 35 mm
- IP20 (receiver) / IP65 (sender)

Figure 1: RES sender & receiver

DT 2.1.2 Please contact Mr. Keller (christian.keller@grossfunk.de) at Gross-Funk for purchasing.

DT 2.1.3 The receiver includes a normally-open (NO) relais which must be part of shutdown circuit. It opens on switching shutdown, on signal loss, and on power loss. Maximum current rating is 4 A.

DT 2.1.4 The CANopen interface of the receiver has the following properties:

- 50 $^{\text{kbit}}/_{\text{s}}$, 125 $^{\text{kbit}}/_{\text{s}}$, 250 $^{\text{kbit}}/_{\text{s}}$ and 500 $^{\text{kbit}}/_{\text{s}}$ in standard configuration.
- Cyclic PDOs containing states of switches (Go-signal) and radio
- Warns if signal loss detected (200 ms in advance to shutdown, contained in cyclic PDO)

DT 2.1.5 The Node-ID and baudrate settings of the vehicle-side installed receiver can be configured with the external DIP switch:

DT 2.1.6 The Node-ID has to be set to 0x011 at the competition. Only in severe cases, there will be an exception. Please give a detail problem description with the request.

[1] https://f.fs-g.org/2017/important_docs/FSG2017_Gross-Funk_v20170126.pdf

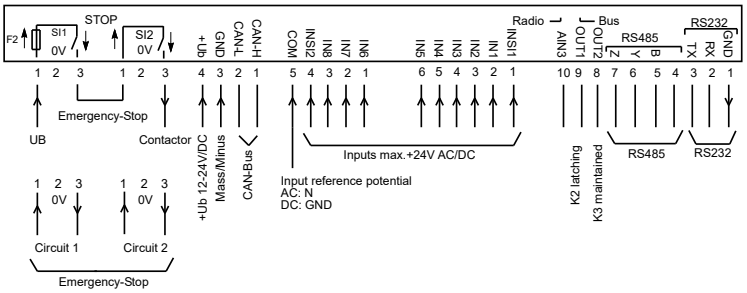

Figure 2: Connections at the RES receiver

DIP SW	1	2	3	4	5	6	7	8	Baud Rate
Node-ID	+1	+2	+4	+8	+16	+32	0	0	50 $^{\text{kbit}}/_{\text{s}}$ (1 $^{\text{Mbit}}/_{\text{s}}$)
Bit	0	1	2	3	4	5	1	0	125 $^{\text{kbit}}/_{\text{s}}$
							0	1	250 $^{\text{kbit}}/_{\text{s}}$
							1	1	500 $^{\text{kbit}}/_{\text{s}}$
	Node-ID						Baud Rate		

DT 2.1.7 There will be a software update provided at the competition allowing 1 $^{\text{Mbit}}/_{\text{s}}$ to be compatible with the FSG Data Logger! Therefore, the 50 $^{\text{kbit}}/_{\text{s}}$ option of the DIP switch will choose the 1 $^{\text{Mbit}}/_{\text{s}}$ baud rate.

DT 2.1.8 The receiver is booted up and sends a message to signalize its initialization (NMT message with CAN-ID 0x700 + Node-ID and a single data byte 0x00). A CAN/CANopen master device must set the receiver to operational mode (NMT message CAN-ID = 0x000, byte 1 = 0x01 (requested state), byte 2 = adressed Node-ID or 0x00 for all). After setting to operational mode, the receiver starts sending a status message of 8 bytes containing PDOs 2000 - 2007 (one byte each, CAN-ID = 0x180 + Node-ID) every 30 ms.

DT 2.1.9 Resetting manually the RES before sending the operational mode message may be used to check if the device is online (NMT message CAN-ID = 0x000, byte 1 = 0x80 (requested state), byte 2 = adressed Node-ID). This will be answered with the bootup message.

DT 2.1.10 Beside the CAN-IDs mentioned in DT 2.1.8 and DT 2.1.9, be aware not to use the CANopen-related IDs listed in Table 1 on the bus[2].

DT 2.1.11 System misbehavior and faulty logs caused by mis-use of these messages eliminates the demand for a re-run and may lead to a Did Not Finish (DNF).

DT 2.1.12 The status of the switch (K2) and the button (K3) at the sender is contained in the PDO 2000 (bit 1 and 2) as well as on the digital outputs. The E-Stop is signalized by PDO 2000 bit 0 and PDO 2003 bit 7. PDO 2006 contains the radio quality (0 % to 100 %) whereas PDO 2007 summarizes several radio states, i.e. the pre-alarm radio communication interruption (bit 6, 200 ms in advandce to shutdown).

DT 2.1.13 Either K2 or K3 are allowed to be used to signalize the Go-signal for switching from “Ready” to “Autonomous” state, see DV 2.4, Table 6. Both the CAN message or the digital outs can be used.

[2] `http://www.canopensolutions.com/english/about_canopen/predefined.shtml`

Communication object	CAN-ID
NMT node control	0x000
Sync	0x080
Emergency	0x080 + Node-ID
TimeStamp	0x100
PDO	0x180 + Node-ID
	0x200 + Node-ID
SDO	0x580 + Node-ID
	0x600 + Node-ID
NMT node monitoring	0x700 + Node-ID
LSS	0x7E4
	0x7E5

Table 1: Reserved message IDs for RES.

DT 2.2 Data Logger

DT 2.2.1 For general information about the data logger, see the specification document in the rules section on the competition website.[3]

DT 2.2.2 The RES and the data logger must share the same CAN bus.

DT 2.2.3 The communication described in section DT 2.1.8 must be traceable in the logs.

DT 2.2.4 Beside RES messages (see DT 2.1.8), the messages defined in Table 2 must be provided to the data logger with a cycle time of 100 ms each. Steering angle δ and vehicle coordinate system is defined in Figure 3.

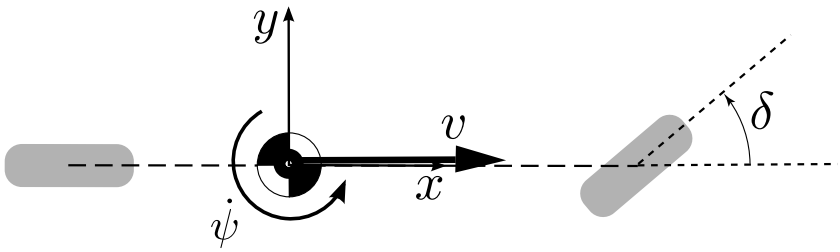

Figure 3: Bicycle model defining steering angle δ (drawn in positive direction after "ISO 8855" coordinate system ⇒ z up) and speed v.

DT 2.2.5 All signals are little-endian (Intel). Scale, if not defined, is 1.

DT 2.2.6 Messages 0x500 and 0x502 must be filled in any case. If some values are not directly available, they should be interpolated or calculated (i.e. target values). 0x501 depends on available sensor data.

DT 2.2.7 All signals mentioned in the team's Failure Modes and Effects Analysis (FMEA) have to be provided within the up to five messages with CAN-IDs 0x511 to 0x515. Each message can be up to 8 B of data length. Cycle time is 100 ms.

[3] https://www.formulastudent.de/fsg/rules/

CAN-ID	Name	Length	Format	Unit	Scale
0x500	DV driving dynamics 1	8 B			
	Speed_actual	bit 0-7	unsigned	km/h	
	Speed_target	bit 8-15	unsigned	km/h	
	Steering_angle_actual	bit 16-23	signed	°	0.5
	Steering_angle_target	bit 24-31	signed	°	0.5
	Brake_hydr_actual	bit 32-39	unsigned	%	
	Brake_hydr_target	bit 40-47	unsigned	%	
	Motor_moment_actual	bit 48-55	signed	%	
	Motor_moment_target	bit 56-63	signed	%	
0x501	DV driving dynamics 2	6 B			
	Acceleration longitudinal	bit 0-15	signed	m/s^2	$\frac{1}{512}$
	Acceleration lateral	bit 16-31	signed	m/s^2	$\frac{1}{512}$
	Yaw rate	bit 32-47	signed	$^\circ/\mathrm{s}$	$\frac{1}{128}$
0x502	DV system status	5 B			
	ASSI_state_off	bit 0	bool		
	ASSI_state_ready	bit 1	bool		
	ASSI_state_auton_mode	bit 2	bool		
	ASSI_state_res_triggered	bit 3	bool		
	ASSI_state_finish	bit 4	bool		
	EBS_state_deactivated	bit 5	bool		
	EBS_state_available	bit 6	bool		
	EBS_state_triggered	bit 7	bool		
	AMI_state_acceleration	bit 8	bool		
	AMI_state_skidpad	bit 9	bool		
	AMI_state_trackdrive	bit 10	bool		
	AMI_state_braketest	bit 11	bool		
	Lap_counter	bit 12-15	unsigned		
	Cones_count_all	bit 16-31	unsigned		
	Cones_count_actual	bit 32-39	unsigned		

Table 2: Message definition of logged general DV data

DT 2.2.8 A valid dbc[4] file containing the message definition of the FMEA messages must be uploaded to the competition website.

[4] see `https://vector.com/vi_candb_en.html` for more informations

DT 3 TRACK MARKING

DT 3.1 General Markings

DT 3.1.1 The markings of all dynamic events will have the following characteristics:

- The track is marked with cones.
- The left borders of the track are marked with small blue cones.
- The right borders of the track are marked with small yellow cones.
- Exit and entry lanes are marked with small orange cones.
- Big orange cones will be placed before and after start, finish and timekeeping lines.
- If not defined otherwise in chapter D of the rules, the maximum distance between two cones in driving direction is 5 m. In corners, the distance between the cones is smaller for a better indication.
- The start, finish, timekeeping lines and keep out zones around the timekeeping equipment are marked with red, orange or pink paint.
- Additionally for skid pad and trackdrive, sprayed border lines on either side of the track and entry/exit lanes are marked with yellow, green or white paint.
- There are no border lines for acceleration and Emergency Brake System (EBS)-test.

DT 3.2 Marking Paint

DT 3.2.1 All lines are spray painted with the chalk-based marking paint “Soppec - Tempo T.P.”[5].

DT 3.3 Cones

DT 3.3.1 The cones used at the competition are equal to the cones listed in Table 3 despite that there will be letters “FSG” on the black/white band of the cones (white/black respectively).

DT 3.3.2 The manufacturer WEMAS[6] does not sell the cones to end customers, but they may be purchase from baustellenabsicherung24.de[7].

DT 3.4 Limitations

DT 3.4.1 There are the following limitations mainly resulting from the Hockenheim track conditions and organizational/authorizational issues:

- The lines may not be perfectly and continuously drawn.
- There may be further markings, to those mentioned above, that are not part of the track (e.g. markings, including cone position markings or lines from other events different colored surface, etc.) on or close to the track which will not be removed by the officials.

[5] http://soppec.com/en/worksite-markers/13-tempo-tp.html
[6] http://www.wemas.de
[7] https://baustellenabsicherung24.de/leitkegel-titan-180-1934.html

			
big orange cone two white stripes	small orange cone single white stripe	small yellow cone single black stripe	small blue cone single white stripe
WEMAS 400.000021.00.00	WEMAS 400.000013.00.00	WEMAS 400.000013.01.10	WEMAS 400.000043.00.00
285 mm × 285 mm × 505 mm 1.05 kg		228 mm × 228 mm × 325 mm 0.45 kg	

Table 3: Cone specs

- No special artificial landmarks are provided by officials. The team must not place additional landmarks on the track or inside the dynamic area.
- No map data is provided by the officials.

DT 3.5 Examples

The following figures visualize the track layout descriptions given in D 4.3, D 5.1, and D 8.1.

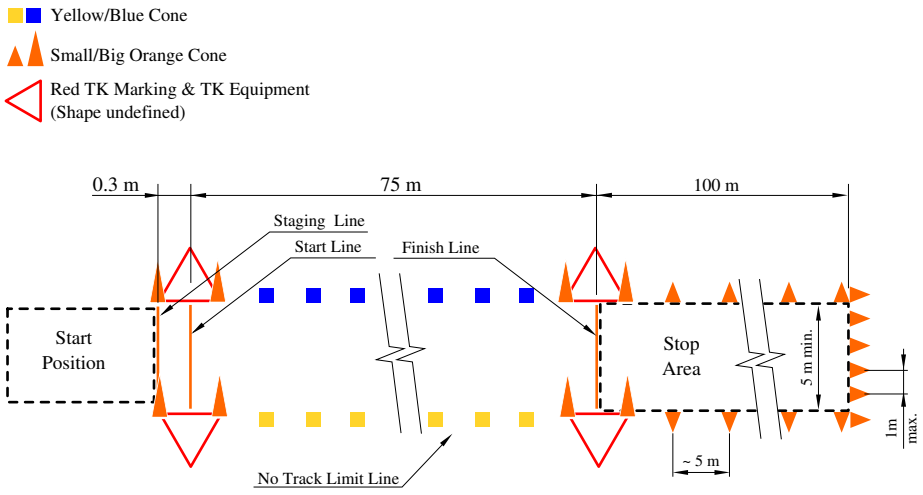

Figure 4: Acceleration

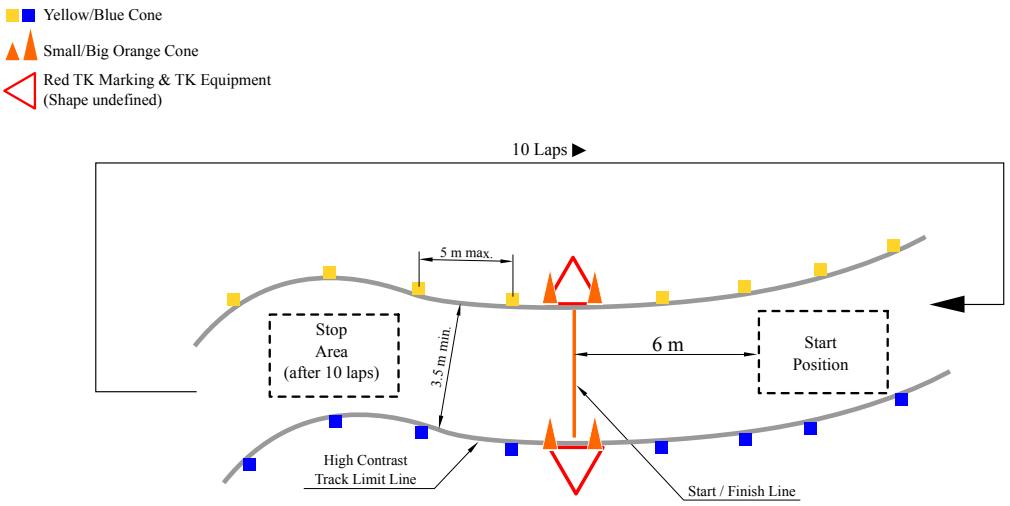

Figure 5: Trackdrive

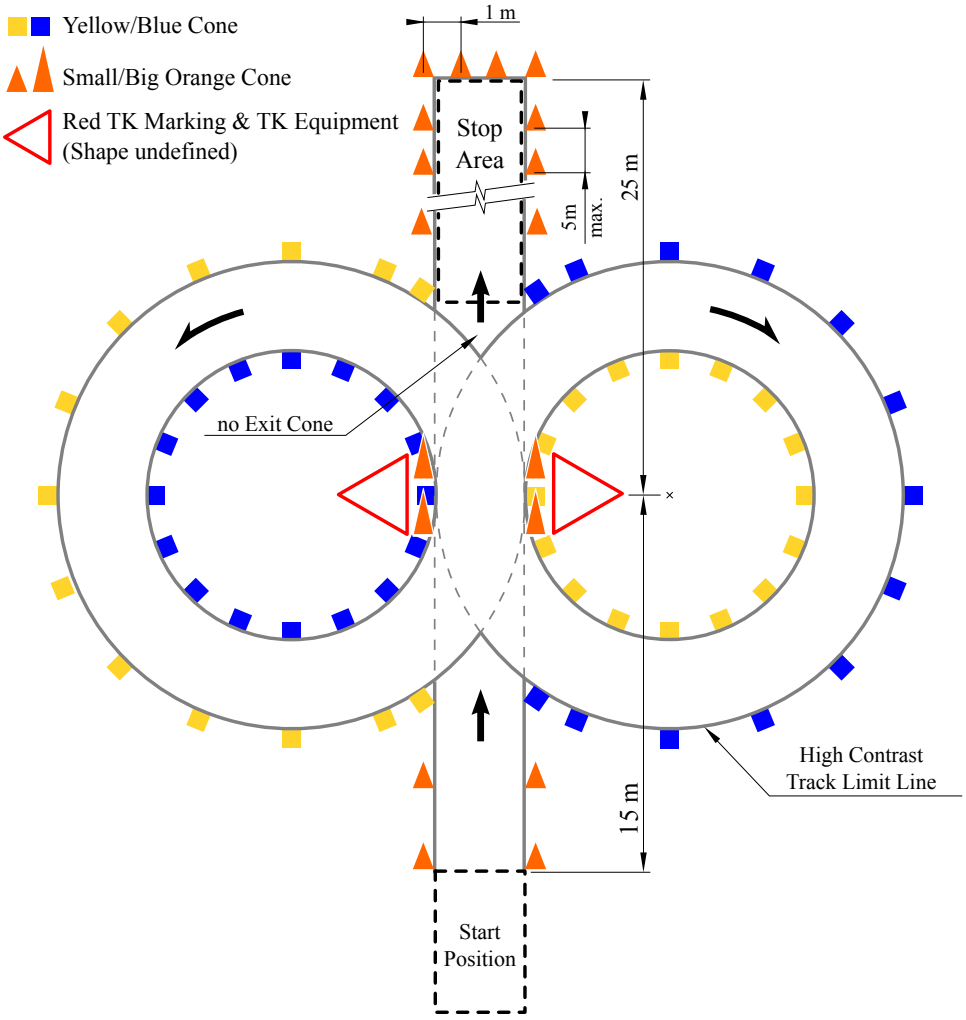

Figure 6: Skidpad base configuration according to rule D4.3