

# FORMULA STUDENT GERMANY

Structural Equivalency Spreadsheet APPROVAL



Car Number

University Name

## Please Note

All teams must submit the SES form and the 3D-CAD model in the team area, on the FSG website, by the official deadline. The uploaded SES form must be checked and approved by a third party or any other competition following the same rules. If any changes to the original SES form have become necessary due to the approval process, the updated final SES form must be uploaded again in the team area. This must be done as soon as the FSG officials have set the previous upload to "Fail". The detailed changelog with all made changes from the "Version History" tab of the SES form must be attached to this SES Approval document.

Reviewing an SES for all given points in the SESA requires at least 3-4 hours which the SES reviewer needs to invest. If the SES reviewer finds some issues he/she should use the change log of the SESA to provide comments. Following, the team must fix or elaborate on the issues and the SES reviewer should recheck these points before submitting the SESA. The complete changelog of the SESA process must be provided with the SESA.

## SES reviewer

Title, Name, Surname

Company

Street

City, Zip

Country

Phone Number

E-mail address

URL

I hereby declare that I have reviewed the SES document and can conclude that the final SES version has passed all requirements listed on the following pages.

**City, Date, Signature, Stamp**



#	SES Tab / Rule	Content	OK
1	Cover Sheet	<b>Cover Sheet</b> duly completed (team name, contact details, international material-nr. or material name, number of layers, layer orientation, core thickness, type of resin)	<input type="checkbox"/>
2		Receipt for used materials, proof for non-steel materials on TAB "Additional Info"	<input type="checkbox"/>
3		Attachment Checklist filled out, see cells T51-56	<input type="checkbox"/>
4	Chassis Pictures	<b>Chassis Pictures</b> colour code for different materials or different composite layups (if asymmetrical layups present, check orientation inner and outer skin in all subsequent TABs)	<input type="checkbox"/>
5		Proof of materials = used materials for different areas?	<input type="checkbox"/>
6		3 different views and an isometric view is shown	<input type="checkbox"/>
7		angle of main and front hoops, angle between main hoop bracing and main hoop, distance from top of main hoop to main hoop bracing attachment, distance from top of front hoop to front hoop bracing attachment, outer diameter and wall thickness of all tubes / monocoque layup? (cross-check with SE3D file)	<input type="checkbox"/>
8		[EV ONLY] HV components included, coloured orange	<input type="checkbox"/>
9		[CV ONLY] Fuel tank and filler neck included, coloured red	<input type="checkbox"/>
10		Holes in members of the primary structure with a cross sectional $>60mm^2$ must be marked with purple (e.g. holes for cooling, service hatch etc.)	<input type="checkbox"/>
11		"Compliance Shown?" Checklist filled out, see cells R12-20	<input type="checkbox"/>
12 1	Material Data	<b>Material data</b> and values for each different laminate must be provided. Also, if applicable, are values for used aluminium (also as in welded condition) provided? And is the used welding method documented and suitable?	<input type="checkbox"/>
13	Tab A2.2 Significant Changes	Are at least two of the following significant changes in the primary structure documented: material type (different lay-up), dimensions, shape and/or angles (e.g. of main/front hoop)? - Reusing an old chassis, with just a new mainhoop does NOT fulfil the intent of the rule. Changes outside of the primary structure also do NOT fulfil the intent of the rule.	<input type="checkbox"/>
14	Tab T3.8 Main Hoop Tubing Rules T3.7 + T3.8	<b>Main Hoop [MH]</b> must be a single piece of uncut, continuous, closed section steel tube	<input type="checkbox"/>
15		<b>MH angle</b> (shown in TAB "Chassis Pics") above the top of the major structure must be inclined less than 10deg from vertical.	<input type="checkbox"/>
16		<b>MH angle</b> below the top of the major structure can be inclined in forward direction at any angle to the vertical, in the rearward direction, maximal 10deg to the vertical	<input type="checkbox"/>
17	Tab T3.9 Front Hoop Tubing Rules T3.7 + 3.9	<b>Front Hoop [FH]</b> angle between the FH and the vertical is inclined less than 20deg	<input type="checkbox"/>
18		<b>FH</b> - Check the evidence of the used values! (Material Data for Aluminium and physical test sample "in welded condition"+ SE3D file)	<input type="checkbox"/>
19	Tab T3.10 Main Hoop Bracing Rules T3.10 + T3.12	<b>Main Hoop Bracing [MHB]</b> must be made of a straight tube, on both sides of the MH; directed in inclination from the main hoop	<input type="checkbox"/>
20		MHB - must be attached to the main hoop no lower than 160 mm below the top-most surface of the main hoop. The included angle formed by MH and the MHB must be at least 30deg.	<input type="checkbox"/>
21		MHB - support made of steel tubes must be properly triangulated to the bottom of the main hoop and upper member of the SIS	<input type="checkbox"/>
22		MHB - Check the evidence of the used values! (SE3D file)	<input type="checkbox"/>
23	Tab T3.10.5 T3.5 MH Bracing Spt Rules T3.10 + T3.4 + T3.5 + T3.16	<b>Monocoque Main Hoop Bracing Support [MHBS]</b> (T3.16 must be applied) 30 kN for each attachment point, for each support 2 M8 Grade 8.8 bolt or 1 M10 Grade 8.8 bolt.	<input type="checkbox"/>
24		MHBS - Check laminate 3 point bending test!	<input type="checkbox"/>
25		MHBS - Check the shear strength of the laminate!	<input type="checkbox"/>

<sup>1</sup> If the ply layup (number of plies, orientation used material) is the same but the core thickness is different, it is still acceptable to use the derived properties from one laminate panel test. If the core thickness is the same but

the number of plies or the orientation or the used material is different than additional test are required (T3.5.3).



26		MHBS attachment - Check the calculation of the welding seam + backing plate perimeter	<input type="checkbox"/>
27		MHBS - Check the evidence of the used values for the weakest cross sectional area, check for the correct measurement (if alternative proof of equivalence is provided) of the cross sectional inertia!	<input type="checkbox"/>
28		MHBS - Check that the laminate's orientation is corresponding with given proof and laminate test!	<input type="checkbox"/>
29	Tab T3.11 T3.5 FH Bracing Rules T3.11 + T3.4 + T3.5	<b>Front Hoop Bracing [FHB]</b> extended to the drivers feet in front direction; attached on both sides, <b>max. 50.0 mm below top of front hoop</b>	<input type="checkbox"/>
30		If FH > 10 degree inclined to the rear, additional support to the rear is required	<input type="checkbox"/>
31		Check laminate 3 point bending test	<input type="checkbox"/>
32		Check the shear strength of the laminate!	<input type="checkbox"/>
33		Check the evidence of the used values for the weakest cross sectional area, check for the correct measurement (if alternative proof of equivalence is provided) of the cross sectional inertia!	<input type="checkbox"/>
34	Tab T3.13 T3.5 Ft. Bulkhead Rules T3.13 + T3.4 + T3.5	<b>Front Bulkhead [FBH]</b> if L-shaped, the EI of the vertical and horizontal axis must be equivalent to steel	<input type="checkbox"/>
35		L maximum 25.0 mm towards to the inside	<input type="checkbox"/>
36		Check dimensions of cut out in 3D-model	<input type="checkbox"/>
37		Shear strength of bulkhead equivalent to a 1.5 mm thick steel plate (T3.13.1)	<input type="checkbox"/>
38		Check laminate 3 point bending test and laminate perimeter shear test (check for correct orientation of inner and outer skin)!	<input type="checkbox"/>
39		Check the evidence of the used values!	<input type="checkbox"/>
40	Tab T3.17.3 IA AI Plate Rules T3.17.3 to T3.17.7 and T3.16.6	<b>Anti-Intrusion Plate [AIP]</b> 1.5 mm steel or 4 mm aluminium or composite material if approval given	<input type="checkbox"/>
41		Attached with min. 8 x 8 mm Grade 8.8 bolts (proof in longitudinal and transversal direction for alternative attachments), or per T3.16.6 proof of equivalence must be provided in Tab T3.16.6 + 3.17.5 Prim. Struct. Att.	<input type="checkbox"/>
42		If composite material check laminate test or results of composite IAD test. Failure of FBH is not allowed!	<input type="checkbox"/>
43	Tab T3.14 T3.5 FBH Spt Structure Rules T3.14 + T3.4 + T3.5	<b>Front bulkhead support [FBHS]</b> check the drivers leg protection	<input type="checkbox"/>
44		In side view max. 50 mm from top of front bulkhead and from front bulkhead back to the front hoop	<input type="checkbox"/>
45		EI of the FBHS must be equivalent to the sum of the EI of the six (6) baseline steel tubes	<input type="checkbox"/>
46		EI of vertical side of the FBHS (T3.14.3) = EI from one baseline tube	<input type="checkbox"/>
47		Check laminate 3 point bending test	<input type="checkbox"/>
48		Shear strength (T3.14.4) min. 4kN	<input type="checkbox"/>
49		Check the evidence of the used values for the weakest cross sectional area, check for the correct measurement (if alternative proof of equivalence is provided) of the cross sectional inertia!	<input type="checkbox"/>
50	Tab T3.15 T3.5 SIS Rules T3.15 + T3.4 + T3.5	<b>Side impact structure [SIS]</b> SIS incl. bottom until 320mm above the lowest inside chassis point <i>geq</i> EI of 3 baseline tubes	<input type="checkbox"/>
51		SIS (up to 320mm above the lowest inside chassis point) $\geq$ EI of 2 baseline tubes	<input type="checkbox"/>
52		Horizontal floor to the middle of the car (on the weakest area) $\geq$ EI of 1 baseline tube	<input type="checkbox"/>
53		SIS between the upper surface of the bottom up to 320mm above the lowest inside chassis point must have an absorbed energy equivalent to two baseline steel tubes -> see Figure 9	<input type="checkbox"/>
54		Shear strength (T3.15.2) min. 7.5kN	<input type="checkbox"/>
55		Check laminate 3 point bending test (see also: energy absorption value must be greater than the absorbed energy of the baseline test)	<input type="checkbox"/>
56		Check the evidence of the used values for the weakest cross sectional area, check for the correct measurement (if alternative proof of equivalence is provided) of the cross sectional inertia!	<input type="checkbox"/>



57	Tab T4.5 T5.5 SHB Rules T5.5 + T4.5	<b>Shoulder Harness Bar [SHB]</b> Stiffness must be equivalent to 1 baseline tube	<input type="checkbox"/>
58		Check measurement of used panel height, see T4.5 Guidance Notes	<input type="checkbox"/>
59		Check laminate 3 point bending test	<input type="checkbox"/>
60		Check the evidence of the used values for the weakest cross sectional area, check for the correct measurement (if alternative proof of equivalence is provided) of the cross sectional inertia!	<input type="checkbox"/>
61	Tab T3.5 Laminate Test Tab T3.5.9 Shear Tests Rules T3.4 + T3.5	<b>3 point bending test</b> test sample 275x500 mm / load applicator Ø100 mm / support span >400 mm (test specimen with closed flanges are NOT accepted)	<input type="checkbox"/>
62		Proof for SIS with 2 baseline tubes (T3.2.1), other different laminate structures (see page 1) require additional tests with baseline materials (T3.2.1)	<input type="checkbox"/>
63		Check rig compliance value (if below >75%, additional test with baseline material required)	<input type="checkbox"/>
64		If same lay-up used in structures with different core thicknesses, check that laminate with thickest core is tested.	<input type="checkbox"/>
65		Calculated absorbed energy from start up to max. 12.7 mm, and within reasonable load carrying capability of the laminate.	<input type="checkbox"/>
66		SIS - Absorbed energy must be equal or bigger than that of the two baseline tubes!	<input type="checkbox"/>
67		<b>Perimeter shear test</b> sample 100x100 mm on a plate with Ø32 mm hole and with a punch of Ø25 mm	<input type="checkbox"/>
68		Compare values from diagram with values from the TAB	<input type="checkbox"/>
69		Check the evidence of the used material values!	<input type="checkbox"/>
70	Tab T3.16 MH & MH B'ing Attachments Rule T3.4.5 + T3.5.9 + T3.16	<b>Main Hoop Attachment</b> Analogue to rule T3.16	<input type="checkbox"/>
71		Check the evidence of the all used dimensions and used material values!	<input type="checkbox"/>
72	Tab T3.16 FH & FH B'ing Attachments Rule T3.4.5, T3.5.9, T3.9.5, T3.9.6, T3.16	<b>Front Hoop Attachment</b> Analogue to rule T3.16, no lower than 50 mm from top of FH	<input type="checkbox"/>
73		Fully laminated in is accepted if a calculation of the equivalence to four attachment points is shown (min. 6 x 30kN)!	<input type="checkbox"/>
74		Check the evidence of the all used dimensions and used material values!	<input type="checkbox"/>
75	In General Tab T3.16 Rule T3.4.5 + T3.16	<b>Hoop Attachment Points</b> each must carry a load of min. 30 kN in each direction	<input type="checkbox"/>
76		Mounting plates, backing plates and inserts must have sufficient shear area, weld area and strength (check shear strength rule T3.16)	<input type="checkbox"/>
77		Mounting plates, backing plates 2 mm steel (NO alternative, NO cut-outs in backing plate, must be near circular or near oval)	<input type="checkbox"/>
78		Each attachment point must have 2 bolts 8mm Grade 8.8 or alternative	<input type="checkbox"/>
79		Front and main hoop bracing attachment 1 bolt M10 Grade 8.8 is acceptable	<input type="checkbox"/>
80		No crushing of the core is permitted rule T3.16.5	<input type="checkbox"/>
81	Tab 3.16.6 & 3.17.5 Prim. Struct. Att. Rule T3.16.6	<b>Primary Structure Attachment of Plates/Panels</b> (e.g. AIP to Bulkhead, Rear TSAC Protection) Equivalency to a minimum number of 8 mm Metric Grade 8.8 bolts, as follows from attached panel/plate outer perimeter	<input type="checkbox"/>
82		Distribution of required number of bolts according to good engineering practises	<input type="checkbox"/>
83		Check the evidence of the all used dimensions and used material values!	<input type="checkbox"/>
84	Tab T4.5 Harness Attachments Rules T4.5 + T5.3	<b>Harness Attachment Points</b> Shoulder and lap belt attachments must be tested (harness attachment bracket incl.)	<input type="checkbox"/>
85		Distance from the test specimen to the load application point must be at least 125 mm away	<input type="checkbox"/>



86		Test specimen should represent the design on the car as driven at a competition	<input type="checkbox"/>
87		Check the panel height in SES with test specimen dimension!	<input type="checkbox"/>
88		Shoulder and lap attachment must support a load of 13 kN, anti-submarine attachment 6.5 kN; lap and anti-submarine at the same attachment point 19.5 kN	<input type="checkbox"/>
89	Tab T1.2.1 T4.8 Firewall Rules T4.8	Datasheet of fire resistant material provided	<input type="checkbox"/>
90		Heat insulation conditions all filled out? And is the firewall concept described? (Concept cannot be solely dependent on tape to be able to pass a rain test)	<input type="checkbox"/>
91		Check the evidence of the used thickness values!	<input type="checkbox"/>

[EV ONLY]

#	SES Tab / Rule	Content	OK
92	Tab EV5 Accumulator Container Rules EV5.4.6 + EV5.5 + T3.16	<b>Accumulator Container</b> Material as given in rule EV5.5.4 or equivalent if equivalence is shown	<input type="checkbox"/>
93		Check used material is fire resistant according to UL94 V-0 or FAR 25.853(a)(1)(i).	<input type="checkbox"/>
94		Protected with a SIS (rule T3.15 + EV 5.5.2)	<input type="checkbox"/>
95		Check that all mandatory proof per the given table is included!	<input type="checkbox"/>
96		Check the evidence of the all used dimensions and used material values!	<input type="checkbox"/>
97		Tab EV5 Acc. Stack Construction Rules EV5.4.6 + EV5.5 + T3.16	<b>Accumulator Container</b> Check that all mandatory proof per the given table is included!
98	Check the evidence of the all used dimensions and used material values!		<input type="checkbox"/>
99	Tab EV5.5. Acc. Attachments Rules EV5.5 + EV 5.5.9	<b>Accumulator Attachment</b> 20 g in vertical direction, 40 g in longitudinal and lateral direction. Calculation, simulation (not stand-alone) and/or physical test required	<input type="checkbox"/>
100		<b>Accumulator container attachment</b> Brackets / backing plates 1.6 mm steel or 4 mm aluminium	<input type="checkbox"/>
101		Check the evidence of the all used dimensions and used material values!	<input type="checkbox"/>
102	Tab EV5.5.4 Alt. Matl - 3pt Bending - Shear, Matls Summary Rules T53.5.1 + EV5.5.4	<b>3 point bending test</b> test sample 275x500 OR 150x275 mm / load applicator Ø100 OR min. Ø10mm if smaller panel is used / support span >400 mm OR >200 if smaller panel is used	<input type="checkbox"/>
103		If same lay-up used in structures with different core thicknesses, check that laminate with thickest core is tested.	<input type="checkbox"/>
104		<b>Perimeter shear test</b> sample 100x100 mm on a plate with Ø32 mm hole and with a punch of Ø25 mm	<input type="checkbox"/>
105		Compare values from diagram with values from the TAB	<input type="checkbox"/>
106		Check the evidence of the used material values!	<input type="checkbox"/>
107		Tab EV5.5.1 & 5.5.2 EV4.4 ACPS TSPS Side & Rear Rules EV5.5.1, EV5.5.2, T3.16, EV4.4	<b>Accumulator Container &amp; Tractive System Protection Structure</b> All components below 350 mm above the ground must be protected against side and rear impact with a structure. Analogue to Tab T3.15 T3.5 SIS!
108	Horizontal floor of the SIS (on the weakest area) $\geq$ EI of 1 baseline tube		<input type="checkbox"/>
109	SIS between the upper surface of the bottom up to 320mm above the lowest inside chassis point must have an absorbed energy equivalent to two baseline steel tubes (T3.15)		<input type="checkbox"/>
110	Shear strength (T3.15.2)		<input type="checkbox"/>
111	Check laminate 3 point bending test		<input type="checkbox"/>
112	Check the evidence of the all used dimensions and used material values!		<input type="checkbox"/>



**Changelog / Comments**

SES Tab / Rule	Comments