Summary

The challenge set by Diverto was to make an as light as possible design for the stick with a maximum budget of €1500. With the request to use a composite material. It soon was clear that it would be impossible to make the entire design out of carbon fiber because of the high material price. Other cheaper fiber materials such as glass or aramid are unsuitable for use in a stiff construction so another way of reducing cost had to be found. A solution was found in combining steel parts from the original stick with relatively thin carbon fiber parts. This would decrease the cost but also increase the weight significantly.

As a start different design concepts were evaluated, this showed that simply adding a layer of steel at the critical parts of the stick would mean a negligible weight reduction. This was caused by the difference in stiffness between carbon fiber and steel. Steel is more than twice as stiff as a carbon fiber laminate, therefore if the combined layers were loaded most of the stress would still be pulled to the steel. In that case the steel would have to be almost as thick as original. It was decided that the front piece of the stick, which gets the most stress in loading mode, would remain in steel. There is very little room to strengthen the laminate around the hinge points which makes steel the best choice for this part. The beam section which gives the stick is length is constructed in carbon fiber which is suited for this application. Most of the rear section is also constructed in carbon fiber, but some non load bearing pieces of steel were added to spread the load introduce by the hinge points.

Next the laminate was configured that was strong and stiff enough. The chosen layup combines unidirectional material with semi isotropic material. This insures good longitudinal and torsion stiffness. To prevent crippling of the laminate a core had to be added, increasing weight and cost.

The design is made by gluing together a number of parts, carbon fiber sides out of plate material and a carbon fiber top out of U profile, steel reinforcement plates at the rear and the entire steel front piece. The stresses on these edges were calculated to determine the area needed to glue them together.

With this last step the design was complete, now it had to be checked if it is possible to make it within the budget and how much weight had been saved. By combining several layers with the same orientation into one thicker layer the amount of work required to create the layup is reduced. To further reduce the cost it was chosen to use fabric with stacked layers instead of woven fabric. This process is cheaper and the laminate is not significantly influenced. The price of the stick comes to €1600 excluding the work required to build the laminate and for final assembly. The weight of the stick is half way between a full steel sick (106 kg) and a full carbon stick (40 kg) at 71 kg.

Concluding the report it can be said that a steel and carbon stick could be made at around the target price. But before a full scale prototype is build it is better to test the glued connections of smaller test pieces to make sure the desired construction works. The test piece should also be used to see whether the laminate is as strong as was calculated using Kolibri [9]. It is a common practice when

using composite material to test pieces before actual construction is started. This is because of the sensitivity of the material to small imperfections, like layup, moisture and temperature during production.

Because of its impact sensitivity the stick is more likely to sustain structural damage than a steel alternative. The advantage of the chosen design is that the tip, which is most likely to get damaged is made out of steel. If the rest of the stick proves to weak for ordinary use it will have to be shielded with extra material. This can be metal which absorbs energy by deforming, but is heavy. Also more composite layers which are not load bearing and can be sacrificed to absorb an impact, this option is lighter but expensive.