ChampCar Technology Application in the Swift Atlantic Racecar

The CART Toyota Atlantic Championship Series is devoted to developing the next generation of drivers, engineers and mechanics. This series is the highest rung in the CART development ladder. The educational aspect of the series is reflected in the design features of the 014.a.

The new 014.a is a descendent of the Swift 008.a. Many aspects of the 008.a were retained to allow 008.a operators to use 014.a parts. The redesign used Swift ChampCar practices, including aero development in the Swift 8 by 9-foot rolling-road wind tunnel, and autoclaved carbon prepreg parts and tooling. All design, analysis, tooling and fabrication were performed on-site. Each car comes with a complete parts manual, gearbox manual, suspension guide and aerodynamics manual. Major investments were made in these documents to bolster the educational value of the package for CART.

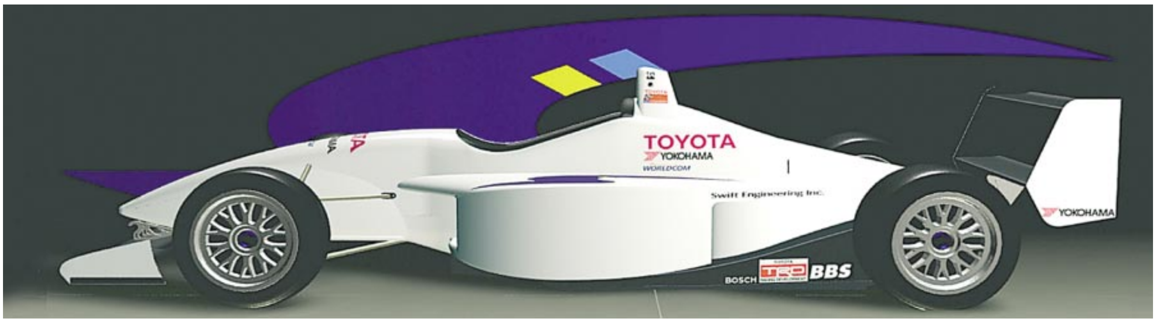


Figure 1: The Swift 014.a Atlantic racecar.

Several safety features were added

The Toyota Atlantic Championship has been sponsored by Toyota for the past 13 years, with Toyota Racing Development (TRD) providing the "spec” engine used by all entrants. The production-based engine develops 240 hp. The racecar weighs 1265 lb loaded and is capable of 160 mph top speed, 4 g cornering acceleration and acceleration from 0 to 60 mph in less than 3 seconds. The Swift 014.a Atlantic racecar is depicted in Figure 1.

Improved Driver Protection and Safety

As part of Swift’s continuous improvement programme, several safety features were added to the 014.a chassis. A tall helmet collar fairing improved driver head protection. A cockpit rim closeout panel was also added to eliminate the abrupt edge to the cockpit rim. Smooth contours reduce the chance of driver injury in a crash and improve driver egress. Improved side-impact protection was achieved with thicker side laminates on the tub. The added material was arranged to add torsional stiffness as well as intrusion resistance.

Improvements were made in part quality through exclusive use of autoclaved pre-preg composite parts, as on Swift’s ChampCars. High-quality bodywork begins with high-quality

Chassis	Carbon/Epoxy Monocoque w/ Aluminum H/C core
Bodywork	Carbon/Epoxy w/ Aluminum H/C core
Wings	Carbon/Epoxy skins + Aluminum hat section spars
Suspension	Steel A-arms + cast Magnesium uprights
Wheels	BBS Forged Aluminum, front 10”x15”, rear 14”x15
Tires	Yokohama racing radials, 250/590-15 F, 350/610-15 R
Brakes	Brembo calipers, Performance Friction rotors
Steering	Rack & Pinion
Engine	Toyota 4AGE 1.6 liter inline 4, DOHC, fuel injected
Cooling	LHS Air/Water radiator
Oil System	RHS Air/Oil radiator, dry-sump, tank in bellhousing
Gearbox	Swift SG3, 5-speed sequential, Aluminum casing
Fuel Cell	15 gallon FIA FT3 approved w/ internal pump
Dimensions	OAL = 167”, WB = 104”, Track = 66”F/61”R

Table 1: 014.a Toyota Atlantic racecar specifications.

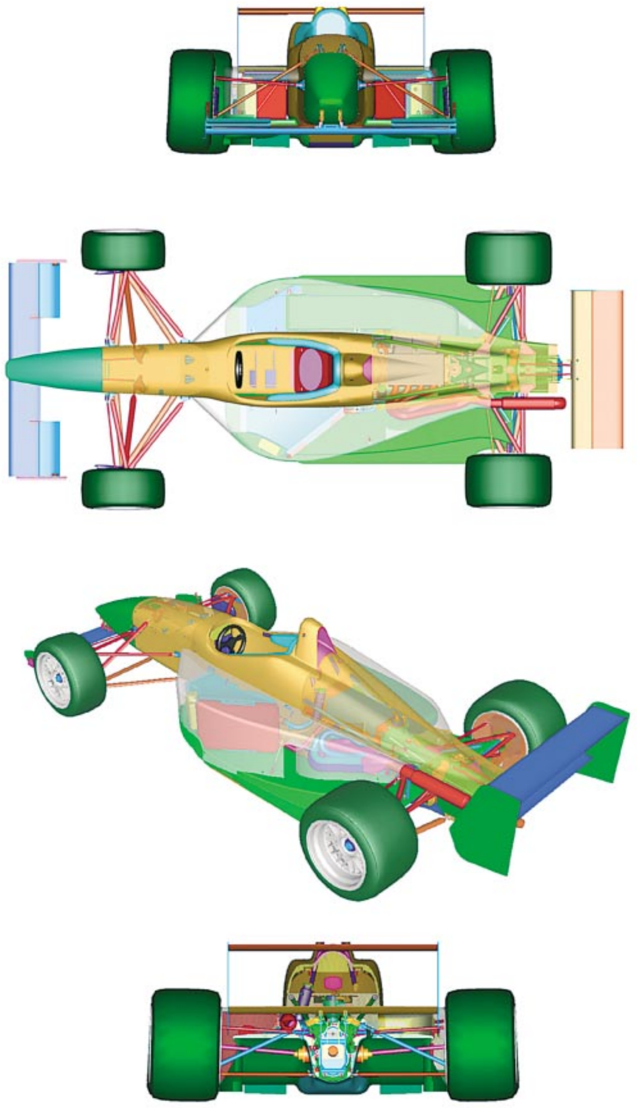


Figure 2: High-quality CAD surfaces.

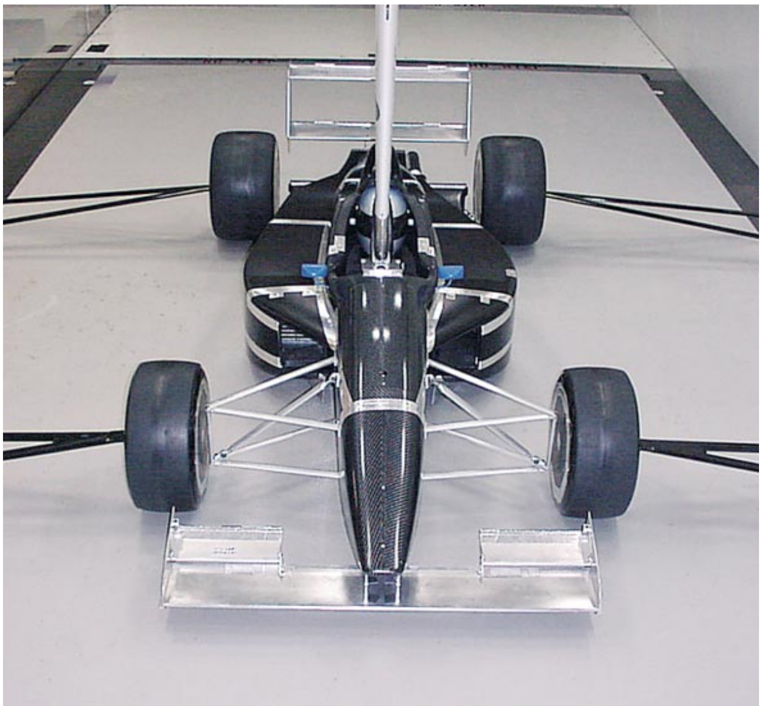


Figure 3: 50 % wind tunnel model.

CAD surfaces, Figure 2. Alias Wavefront Auto Studio, and SDRC Ideas, were used to generate surfaces. Mould design followed directly from part design. Trim lines and drill bushings for fasteners were designed into the moulds. Parts were drilled before de-moulding, with the result that the moulds now doubled as drill-off jigs for consistent and accurate fastener location.

A development series racecar should have performance marginally lower than a top-rung car

Aerodynamic Development

A development series racecar should have performance marginally lower than a top-rung car, yet retain the same adjustability to train the drivers and engineers. Table 2 shows the comparison between a ChampCar and an Atlantic Car in high downforce (high drag) trim at typical ride heights. Forces are quoted for standard day conditions at 200 mph. Cornering speed is based on a friction coefficient of 1.5, and maximum speed assumes 15 % transmission/slip losses. All units are pounds-force, horsepower and mph.

Atlantic downforce to weight ratio is shown to be slightly lower than the ChampCar. However, hp/weight ratio is only 40 % of the ChampCar value. Since the engine was not changed for the 014.a, it was not possible to improve acceleration. Instead, a 10 % drag reduction was sought to improve top-end speed.

Performance Development

Starting with the 008.a baseline configuration, 014.a features were developed in-tunnel with a 50 % scale model, Figure 3. First, the region surrounding the driver's helmet was revised for safety. This was then blended into the engine cover for drag reduction. Downforce was improved with a re-contoured diffuser and more powerful Vortex Generators (VG's). Figure 4 shows the streamline traces on the underwing with the new VG's.

Sidepod development focused on simpler lofting and a larger

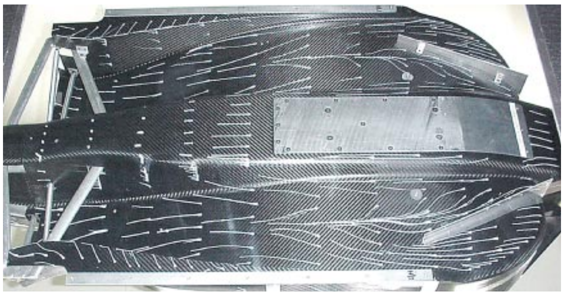


Figure 4: Streamline traces on the underwing with the new Vortex Generators.

Figure 5: In order to improve cooling, intake area was increased to reduce duct losses.

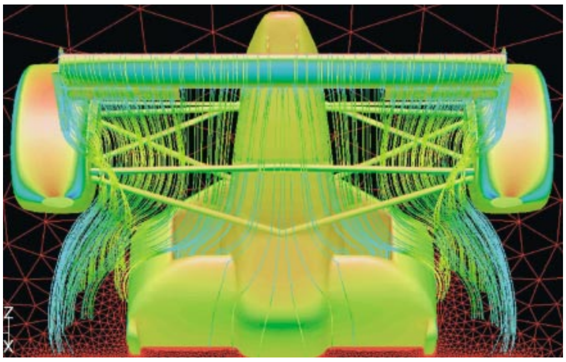


Figure 6: Computational Fluid Dynamics (CFD) showed that the larger intake did not ingest the front flap vortex as feared.

radiator intake. Extending the sidepod leading edge improved aero balance and extended the side-impact crush structure forward, thus improving safety.

CART had announced plans to race at high-elevation venues where cooling would be a bigger problem. Tracks like Denver (5,000 ft above sea level) require about 14 % more exotherm capability. In order to improve cooling, intake area was increased to reduce duct losses, Figure 5. A 15 % face velocity improvement was achieved. Computational Fluid Dynamics (CFD) showed the larger intake did not ingest the front flap vortex as feared, Figure 6.

Aero-Mapping

The 014.a was thoroughly mapped in four separate tests. An example AeroMap is shown for a maximum downforce case in Figure 7. The graph depicts downforce (lbs force) vs. rear ride height (inches) for constant front ride heights. Downforce and drag can be reduced by approx. 35 % by reducing airfoil incidence and removing the Gurney flaps. No additional parts are needed to convert from high to low-downforce trim. The downforce behaviour is smooth with some roll-off at low front ride heights. This characteristic is similar to ChampCars.

The 014.a racecar provides an extreme downforce range for the operator. In order to aid the race engineer in exploring these alternatives, Swift developed an automated AeroMap tool called "DigiMan„", which stands for Digital Aero Manual. This optional software allows the race engineer to rapidly evaluate dozens of aerodynamic set-ups. The input page of DigiMan„ is shown in Figure 8. Here, the user enters all nine aerodynamic variables for the racecar. Downforce, drag, lift-to-drag ratio (L/D) and balance are instantly calculated. A full AeroMap can then be plotted for any set-up. Team response has been positive to DigiMan. This software is another way for new Atlantic teams to quickly get up to speed on the 014.a.

The 014.a racecar was track tested at the Buttonwillow road course in California and Phoenix International Raceway in Arizona. Calibrated suspension pushrods were used to determine track downforce and balance levels for several configurations. Compared to the wind tunnel data, the standard deviation on downforce for all conditions was less than 1 % with a worst-case difference of 2.6 %, an excellent correlation.

Mechanical Development

Mechanical enhancements were focused on torsional stiffness and weight reduction. Stiffness increases were due to additional 45-degree plies in the chassis laminate, as well as improved engine bay trunnions, added laminates for side-impact pro-

Table 2. Performance comparison between Atlantics and ChampCars.

Roadcourse Performance Comparison	Atlantic 008.a max DF	Atlantic 014.a @ 008.a DF	Atlantic 014.a max DF	2000 ChampCar max DF
Weight	1265	1265	1265	1750
Horsepower	240	240	240	850
Downforce	3200	3200	3550	5000
Drag	1030	940	1050	1700
Drag Limited Top Speed	145 mph	149 mph	144 mph	189 mph
Grip Limited Cornering Speed				
R = 200 ft	79 mph	79 mph	80 mph	80 mph
R = 300 ft	108 mph	108 mph	113 mph	115 mph
R = 400 ft	143 mph	143 mph	157 mph	160 mph
L/D	3.1	3.4	3.4	2.9
DF/Weight	2.5	2.5	2.8	2.9
HP/Weight	0.19	0.19	0.19	0.49

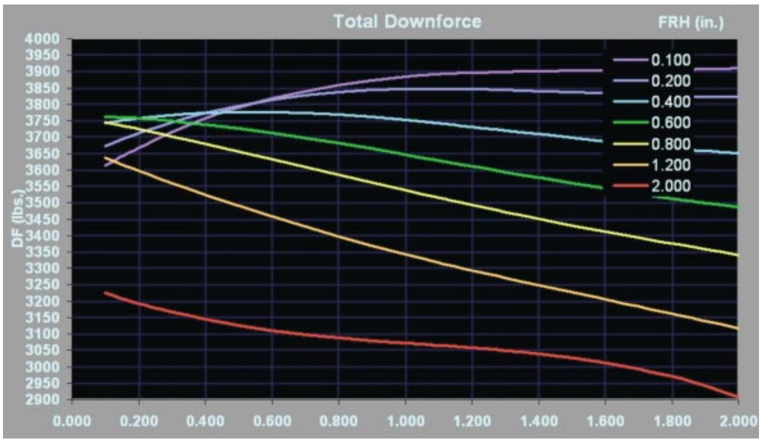
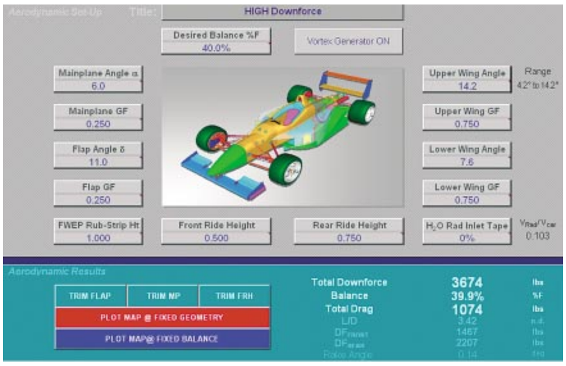


Figure 7: Example AeroMap for a maximum downforce case.



Title: HIGH Downforce
Desired Balance %F: 40.0%
Vortex Generator ON
Mainplane Angle α: 6.0
Mainplane GF: 0.250
Flap Angle δ: 11.0
Flap GF: 0.250
FWEP Rub-Strip Ht: 1.000
Front Ride Height: 0.500
Rear Ride Height: 0.750
Upper Wing Angle: 14.2 (Range 4.2° to 14.2°)
Upper Wing GF: 0.750
Lower Wing Angle: 7.6
Lower Wing GF: 0.750
H_2O Rad Inlet Tape: 0% (V_{Rad}/V_{car} 0.103)

Total Downforce	3674	lbs
Balance	39.9%	%F
Total Drag	1074	lbs
L/D	3.42	n.d.
DF_{front}	1467	lbs
DF_{rear}	2207	lbs
Rake Angle	0.14	deg

Figure 8: DigiMan, input page.

tection, the cockpit rim closeout panel and the new gearbox.

Table 3 summarizes stiffness for the 008.a and 014.a. Driver feedback confirmed the improvements.

The SG3 gearbox for the 014.a is a sequential shift, 5-speed plus reverse, dog clutch design. Swift designed the gearbox in partnership with Hewland Engineering Ltd., Figure 9. Despite the extra torque capability, the SG3 weighs slightly less than its predecessor, due to better structural efficiency.

The shift forks were arranged to slide concentrically with the selector barrel to balance the overturning moments. The barrel is axially constrained by a compliant mount to absorb the kickback forces of a dog-to-dog missed shift. The choice of ratios was rationalized to 50, with well-spaced splits throughout the range. The final drive ratio is 9/34. The gear selector mechanism and oil pump were moved from the rear of the gearbox forward to a less vulnerable location in a rear impact.

Documentation

The Suspension Guide contains basic chassis set-up information to aid less experienced teams with initial settings for both road and oval type tracks. This provides a baseline that can be further developed for each track and driver. The Aero Manual is essential for teams to understand the ride-height characteristics and adjustment sensitivities of the 014.a. This eliminates the need for on-track aero mapping. The Parts Manual features illustrations taken directly from the CAD models.

Conclusion

A new-generation Toyota Atlantic Racecar, the 014.a, has successfully completed its first season of racing. The 014.a set qualifying and fast lap records at virtually every 2002 race venue. Designed and manufactured by Swift Engineering Inc, the 014.a is a significant improvement over the previous model. Driver feedback has been extremely positive. Customers have expressed satisfaction in the areas of part quality, fit, durability, ease of maintenance, handling response to chassis adjustment, documentation and reliability. The Swift 014.a is the most reliable and cost-effective spec open-wheel racecar in competition today.

by Mark Page, Tom Huschilt, Chris Norris, Neil Roberts, Swift Engineering Inc., San Clemente, USA.

The Aero Manual is essential for teams to understand the ride-height characteristics

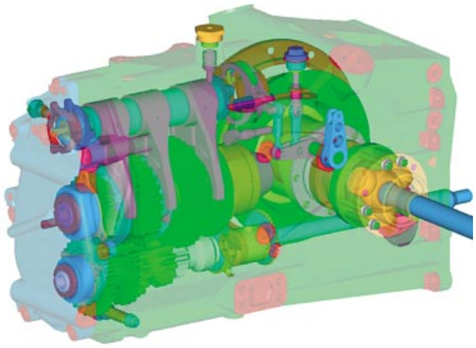


Figure 9: Swift designed the gearbox in partnership with Hewland Engineering Ltd.

Configuration	*Torsional Stiffness (Ft*lb/deg)*	*% Increase from baseline*
008.a with trunnions	*3,882*	*Baseline*
014.a with trunnions	*5,110*	*+32%*
008.a chassis only	*13,222*	*Baseline*
014.a chassis only	*19,144*	*+45%*

Table 3. Chassis stiffness breakdown.