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It's Lights Out and Away We Go

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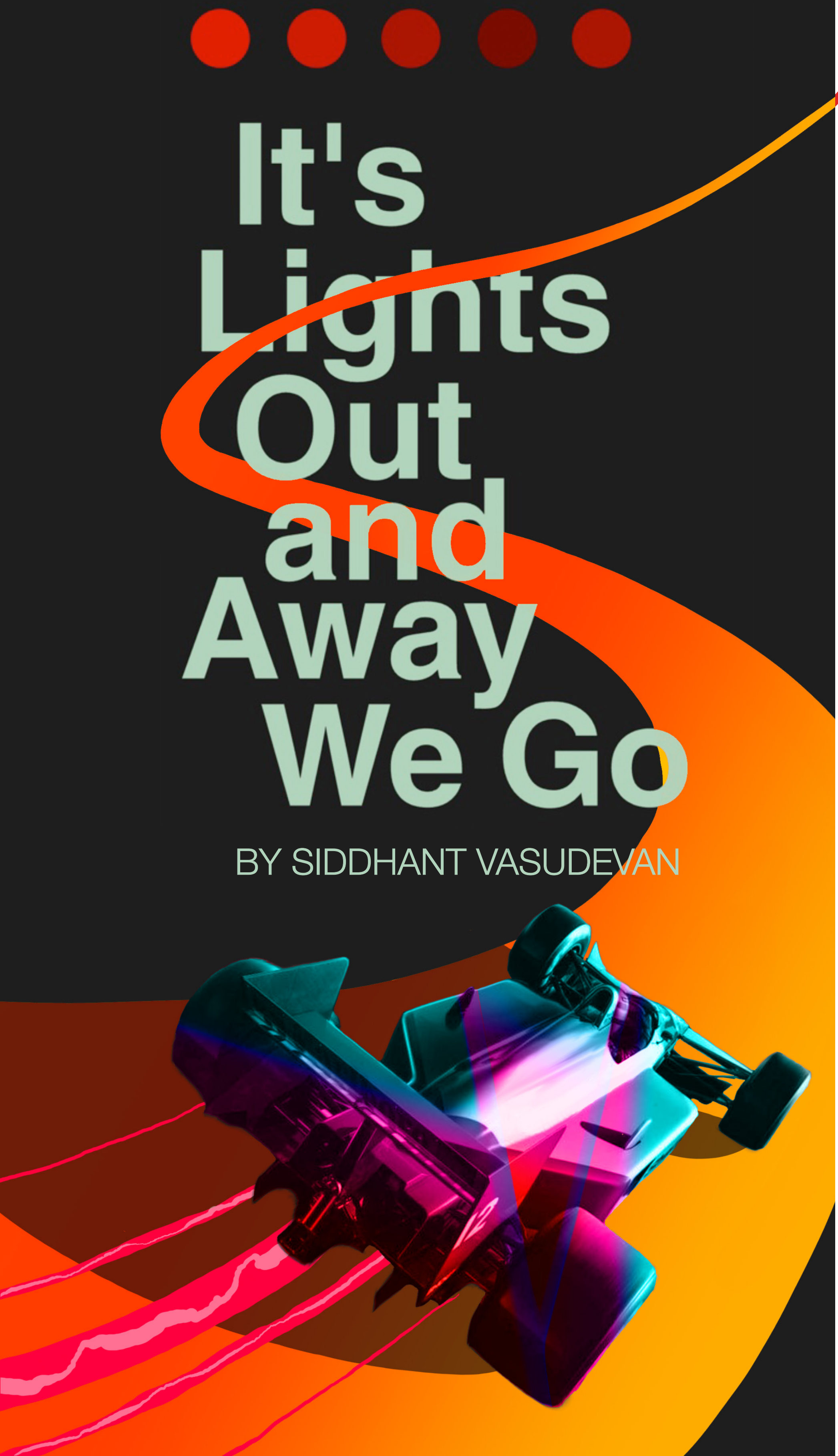

One by one, five red lights illuminate above a sea of cars that lie impatiently on the asphalt. As the lights shine, the sound of roaring engines is replaced with a moment of silence; fans and drivers all holding their breaths—waiting. And then, just as quickly as it came, the silence is shattered, and all five lights disappear.

"It's lights out and away we go!"

This iconic phrase marks the beginning of every race in Formula 1, the highest level of motorsport, in which 10 teams—or constructors—design cars every year for their two drivers. The result is twenty cars and drivers racing on tracks across the world. While motorsport fans in the United States may be more familiar with races around an oval track, operated by The National Association for Stock Car Auto Racing (NASCAR), Formula 1 is known for its complex tracks with a mix of sharp turns, sweeping high speed curves, and narrow corridors that drivers must navigate at speeds of up to 320 km/h (200 mph). In order to make these daring feats possible, teams must engineer a car not only capable of conquering these conditions, but one that can do so while jockeying for positions in a race.

As a result of the sport's competitive nature, each and every car embodies the forefront of automotive technology and design. More specifically, attempts to make Formula 1 cars faster have prompted some of the world's leading aerodynamics research. Since the first Grand Prix in 1950, Formula 1 cars have experienced some of their most dramatic improvements as engineers and researchers have gained a deeper understanding of aerodynamics.[1]

However, the cars are also becoming increasingly dependent on their aerodynamics. The cars have trouble following one another, reach cornering speeds that many consider dangerous, and are becoming so fast that we may be nearing the human limit. In recent years, the sport has witnessed an increase in rules and regulations that make racing closer—rather than faster.[2] The focus is now on making the racing more competitive, and as a result, the rate at which Formula 1 cars are getting faster may be plateauing.[3] The science of motorsport is confined by the necessity of a delicate balance between entertainment and pushing engineering limits. Now, that balance is beginning to be tested.

THE BIRTH OF DOWNFORCE

At the beginning of Formula motorsport, the cars were not a complex amalgamation of wings, panels, and shapes that manipulate how air flows around the car. In order to minimize aerodynamic drag, the resistive force on a body as it moves through air), early Formula 1 car designers worked to make their cars smaller and more streamlined, which led to a lot of thin, rounded, bullet-like cars.[4] This concept was already well established in the design of planes, but it had a fundamental flaw when it came to getting cars around a race track—cars must interact with the ground.[5] While these streamlined shapes allowed the car to cut through the air with minimal resistance, they contrastingly made the cars struggle to go around any corners. At times, the air traveling under the cars generated lift—lifting the cars into the air and flipping them.[6]

Throughout the 1960s, one team began developing a new approach. Colin Chapman, the founder of the automotive company Lotus, is largely credited with changing the philosophy of aerodynamics on Formula 1 cars from 'attempting to go fast despite the air passing the car,' to 'going faster with the help of air passing the car.' His work began from the understanding that cars become significantly faster around the corners when they make better contact with the ground. Since the friction between a tire and the ground pulls a car inward during a corner, one can increase the cornering speeds by increasing the force with which the car is pushed downward[5]. In order to increase this force, Chapman could have added weight to the car; however, it takes more energy to accelerate, decelerate, and change the direction of a heavy body than it takes for a lighter one. Therefore, Chapman looked to aerodynamics.

On a plane, the curvature of an aerofoil creates a pressure gradient above and below the wing since the air following the curved upper surface will decrease in pressure. Because there is more pressure below the wing, the wing is pushed upward.[7] Since Chapman wanted the opposite effect, he flipped the conventional airplane wing upside down so that instead of generating lift, it generated what is known as downforce.[8] Though these wings added drag, the benefits around corners were able to offset any decrease in straight-line speed.[3] Thus the Lotus 49, first driven at the 1968 Monaco Grand Prix, was the first Formula 1 car to incorporate "wings," marking the beginning of an aerodynamics revolution in the sport.[9]

Continuing to optimize the downforce of their cars, Chapman and his team raced the Lotus 78 for the first time in 1977. By lowering the car to be just barely above the ground, shaping the bottom of the car into a smooth wing profile, and placing walls on either side, the car was able to create narrowing tunnels for the air under the car, a concept known as "ground effect downforce."[8] In other words, the car was suctioned to the ground because the air flowing underneath traveled much faster at a low pressure.[10] The Lotus 78 and its successor, the Lotus 79, were extremely successful, with the latter winning 8 of the 16 races in the season and securing the championship for the team and driver by a comfortable margin.[11] However, Lotus was no longer the only ones developing downforce, and in 1978, the Brabham team created a car that pushed the limit of how far teams were willing to go. The Brabham BT46B, designed by Gordon Murray, took ground effect to the extreme by attaching a fan to the back of the car that sucked more air underneath the car, thereby generating even more downforce than the natural flow of air around the car.[12]

If you have ever wondered why golf balls have indents in them, the answer is aerodynamics. When golfers realized that older, more dented balls traveled further than their smooth counterparts, researchers investigated the phenomenon. Normally, a sphere moving through the air creates a pocket of low pressure behind it which acts as a vacuum and pulls the sphere backward. However, the dimples on a golf ball make the boundary layer of air more turbulent, giving it more energy to stay on the surface of the ball and allowing the air to fill in more of the low pressure zone behind the ball.[13] Formula 1 cars have been designed in a similar fashion; they have been "dented" in all the right places in just the right way to make them move through the air and produce downforce efficiently.[14] In fact, the cars today can produce more than their weight in downforce, which means that theoretically—and at high enough speeds—they could be driven on the ceiling.[15]

CAUGHT IN DIRTY AIR

Although aerodynamic innovation has driven the sport for years, many incredible innovations of the past have fallen. Years ago, each car looked wildly different from the next, as each constructor paved their own radical design; however, cars today look almost identical since innovations that are extreme are likely to be removed so that racing remains competitive.[15] For example, ground

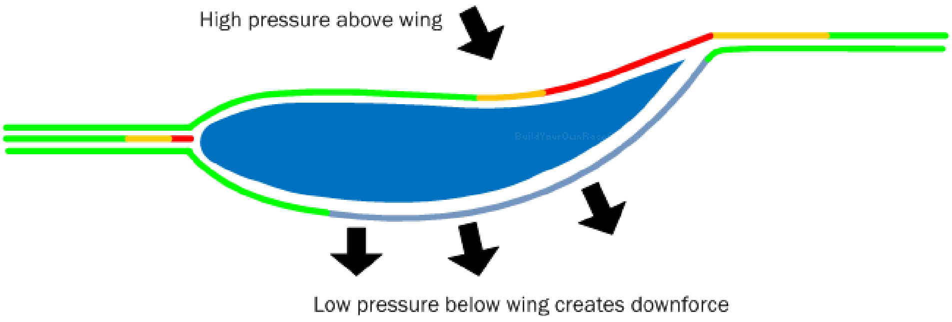

Figure 1: An inverted airplane aerofoil generates downforce. *The curvature of a wing creates a region of lower pressure and higher pressure; by orienting the low pressure region below the wing, the wing is pulled downward.*

Figure 2: ***The Lotus 78 was the first car which utilized "ground effect" downforce.*** *The channels on either side of the car led air into large curved surfaces which acted as wings across the entire underside of the car.*

effect was greatly limited from the sport even though it was the most significant aerodynamics innovation of the time, and the BT46B "fan car" was banned from competing, even though it won its first—and only—race.[12] Starting next year, even some of the basic aerodynamic surfaces on the cars are coming under the scrutiny of Formula 1's governing body.

Currently, Formula 1 car aerodynamics have become increasingly complex as the teams strive to outdo one another. But, the issue with this approach is that in creating the most optimized aerodynamic setup, the quality of the racing is decreasing. For instance, F1 cars today struggle to overtake each other, because when one car comes behind another, it is hit by what is known as "dirty air."[16] The aerodynamic surfaces have all been designed to work in clean, smooth and non-turbulent airflow; the air behind a car is anything but that.[17] All the layers of complexity and innovation leave a trail of turbulence behind each car.[14] In attempting to overtake, a car can lose grip and ultimately struggle to remain competitive.

A large part of the allure of racing is to see the cars overtaking each other in daring, brilliant moves—shaking up the outcome of each race. And thus, to address dirty air, 2022 marks a major change in Formula 1: the cars are being completely redesigned.

THE FUTURE OF FORMULA 1

The aerodynamic surfaces on the car are being reshaped—and ultimately simplified—in a bid to make the cars more capable of coping with turbulent air. The current cars create significant amounts of turbulent air, especially from the wheels. Since the cars are meticulously designed to work in smoothly flowing air, all of this turbulence that is pushed out from the sides and behind the car can cause cars behind to experience downforce losses of up to 45%. For 2022, teams and the governing body claim to have found ways to drop that number down to 14%.[18] The front wing and new additional wings over the wheels plan to control the wake from the wheels and keep it over the body of the car, while the aerodynamic components throughout the body and rear wing will push the air up and over the cars behind.[19] With the simplified geometry of the car comes more resilience to turbulence, and therefore, allows the cars to closely follow behind each other.[14] Though many other major components such as the engines are unlikely to have major changes, the aerodynamic regulations mark a new era of Formula 1, and as one of the largest changes since 2014, it will likely reset the playing field.

Currently, improvement comes at the cost of entertainment, so as part of the redesign for next year, Formula 1 is taking a step back. With all these aerodynamic simplifications and new regulations considered, the cars next year are almost certainly going to be slower than the ones this year. But the simple fact is that Formula 1 is a sport; it is entertainment as much as it is engineering. Perhaps that is its allure. There is something so fundamentally beautiful in putting engineering on the competitive world stage—inspiring the next generation of engineers and demonstrating the cutting edge of human capabilities.

So when "it's lights out and away we go"—when we take the plunge in this new direction—we can do so with an understanding. An understanding that for many, these cars are more than just a source of entertainment: they are beautiful symbols of humanity's engineering potential.

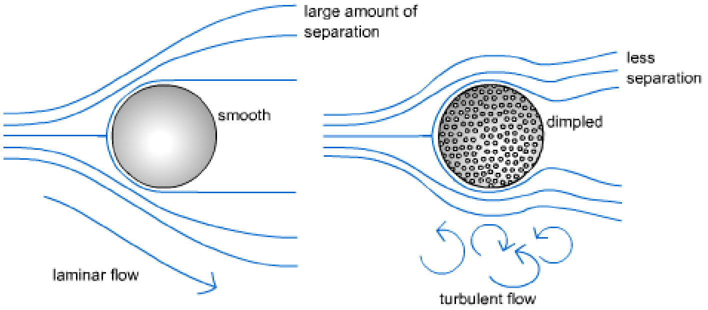

Figure 3: The aerodynamics of a golf ball. *The dimples on the ball allow the air to follow the surface of the ball for longer. This creates a narrower region of low pressure behind the ball than is created by a smooth sphere.*

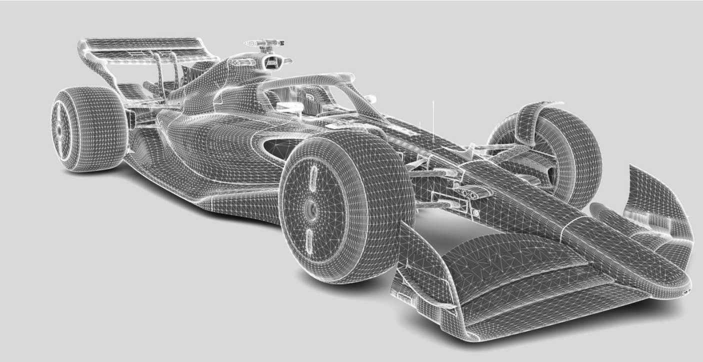

Figure 4: The 2022 Formula 1 cars are more sleek with simplified aerodynamic components.

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REFERENCES

1. Codling, S. (2017). Speed read F1: *The technology, rules, history and concepts key to the sport.* Motorbooks.
2. Mafi, M. (2007, November 21). *Investigation of turbulence created by ... - f1-forecast.com*. Congress Center Dresden, Germany. Retrieved February 17, 2022, from https://www.f1-forecast.com/pdf/F1-Files/Investigation%20of%20Turbulence%20Created%20by%20Formula%201%20Cars%20with%20CFD.pdf
3. Katz, J. (2021). Aerodynamics in motorsports. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 234*(4), 324–338. https://doi.org/https://doi.org/10.1177/1754337119893226
4. Fields, Joshua, “How Advancements in Aerodynamics Improves the Performance of Formula 1 Racecars” (2015). *Honors Theses*. 300. Retrieved February 17, 2022, from https://digitalworks.union.edu/theses/300
5. Toet, W. (2013). Aerodynamics and aerodynamic research in Formula 1. *The Aeronautical Journal (1968), 117*(1187), 1-26. doi:10.1017/S0001924000007739
6. Perkins, C. (2020, July 28). *Why some race cars kept backflipping in the late 1990s.* Road & Track. Retrieved February 17, 2022, from https://www.roadandtrack.com/motorsports/a25949868/mercedes-clr-le-mans-crash-analysis/
7. Babinsky, H. (2003, November). *How do Wings Work?* IOP. Retrieved February 17, 2022, from http://www3.eng.cam.ac.uk/outreach/Project-resources/Wind-turbine/howwingswork.pdf
8. Ayushman. (2020, June 29). *Aerodynamics in formula 1*. The GSAL Journal. Retrieved February 17, 2022, from https://thegsaljournal.com/2020/06/28/aerodynamics-in-formula-1/
9. Hasanovic, V. (2018, April 3). *Formula 1 Aerodynamics - Introduction*. F1technical.net. Retrieved February 17, 2022, from https://www.f1technical.net/features/21555
10. Ogawa, A., Mashio, S., Nakamura, D., Masumitsu, Y., Minagawa, M., & Nakai, Y. (2009). *Aerodynamics analysis of Formula one*. f1-forecast.com. Retrieved February 17, 2022, from http://f1-forecast.com/pdf/F1-Files/Honda/F1-SP2_21e.pdf
11. *Tech Tuesday: The lotus 79, F1’s Ground Effect Marvel*. Formula 1® - The Official F1® Website. (2018, August 21). Retrieved February 17, 2022, from https://www.formula1.com/en/latest/technical/2018/8/tech-tuesday-retro-lotus-79.html
12. Somerfield, M. (2020, October 7). Banned: The full story behind Brabham’s F1 ‘fan car’. Retrieved February 17, 2022, from https://us.motorsport.com/f1/news/banned-tech-brabham-bt46b-fan/4808235/
13. Veilleux, T., & Simonds, V. (2005, September 19). *How do dimples in golf balls affect their flight?* Scientific American. Retrieved February 17, 2022, from https://www.scientificamerican.com/article/how-do-dimples-in-golf-ba/#:~:text=Dimples%20on%20a%20golf%20ball,the%20size%20of%20the%20wake.
14. Hasanovic, V. (2018, August 14). *Formula 1 Aerodynamics – Basics of Aerodynamics and Fluid Mechanics, part II*. F1technical.net. Retrieved February 17, 2022, from https://www.f1technical.net/articles/
15. BBC. (2019, March 15). Formula 1: *The secret aerodynamicist reveals design concepts*. BBC Sport. Retrieved February 17, 2022, from https://www.bbc.com/sport/formula1/47527705
16. Toet, W. (2019, April 18). *Willem Toet explains...the 2019 F1 aerodynamic dilemma*: Race Tech Magazine. Race Tech Magazine. Retrieved February 17, 2022, from https://www.racetechmag.com/2019/03/willem-toet-explains-the-2019-f1-aerodynamics-dilemma/
17. Neborn, J. J., & Somiy, R. G. (n.d.). *The International Vehicle Aerodynamics Conference.* Durham university .
18. Elson, J., Forster, K., Oxley, M., Williams-Smith, J., & Hughes, M. (2021, July 26). *How F1’s 2022 rules should bring closer racing: Aero changes explained.* Motor Sport Magazine. Retrieved February 17, 2022, from https://www.motorsportmagazine.com/articles/single-seaters/f1/behind-the-scenes-of-f1s-new-2021-rules-and-why-they-could-work
19. Miller, C. (2021, July 16). *New 2022 F1 car promises better aerodynamics, closer racing.* Car and Driver. Retrieved February 17, 2022, from https://www.caranddriver.com/news/a37038474/2022-f1-car-revealed/

IMAGE REFERENCES

20. *Car Aerodynamics Basics and How-To Design Tips cont....* (n.d.). Build Your Own Race Car.
21. *Mario Andretti, Lotus 78, Monza.* (2020). Flickr. Retrieved February 17, 2022, from https://www.flickr.com/photos/52605354@N06/50033136942.
22. Gu, J. (n.d.). *Microscopic Surface Textures Created by Interfacial Flow Instabilities.* SemanticScholar. Retrieved February 17, 2022, from https://www.semanticscholar.org/paper/Microscopic-Surface-Textures-Created-by-Interfacial-Gu/4139173fbaf8ff0f397c238a3cf3c5a14b676321.
23. racesimstudio. (2021). Livery Templates - Formula Hybrid X 2022 & EVO - Assetto Corsa.