

PROJECT - 7 SYSTEM-LEVEL MODELING OF A FUEL CELL VEHICLE FOR TOP SPEED RUN CONDITIONS

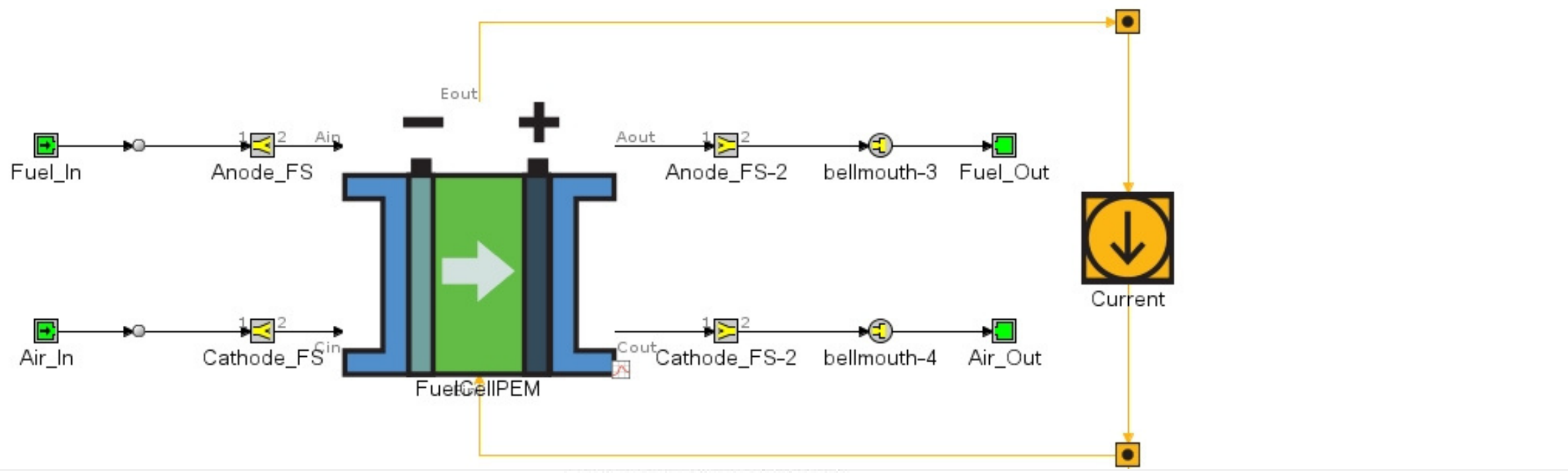
1. INTRODUCTION

Fuel cells are gaining popularity as they have a variety of applications ranging from personal vehicles to trucks, and also race cars. A fuel cell is able to produce cleaner and more efficient electrical energy for propulsion and is also able to supply electric power on demand when necessary as opposed to an IC engine. By simulating a fuel cell system for the Ford 999 racecar we want to study the performance of a Fuel cell system under extreme and high performance conditions which is highly demanding on the system in terms of multiple factors like power output, torque produced to name a few. The working principle of a fuel cell is that it is an electrochemical device that converts chemical energy (fuel) directly into electrical energy and this can be used for propulsion in a vehicle and also to power its auxiliary systems and also recharge its batteries.

The Fuel cell is however more expensive than a battery and has a smaller temperature operating window. They are also more sensitive to external factors and contaminants in the system.

- In this project we use a FCEV model available on GT-Suite. This was a demo model which simulates the performance of a normal FCEV in normal conditions.
- This model works by running a Fuel cell system which generates electrical power, which is then fed into a DC-DC converter and then into an electric motor for propulsion of the vehicle.
- The driving conditions and other factors are controlled by the Vehicle and Battery controller modules.
- We are able to get a variety of results from this model such as mass of fuel consumption, the maximum speed and minimum speed of the vehicle, the maximum acceleration to name a few.
- From this model we are able to simulate our vehicle the Ford 999 as well, by tuning the model and simplifying it for our project.

4. RESULTS : SIMULATED MODEL V/S BASIC CALCULATIONS



Measured parameters	Calculated values	Simulated values
Oxygen usage	9.06 kg	8.23 kg
Air usage	42.3 kg	36 kg
Hydrogen usage	1.89 kg	1.16 kg
Heliox usage	5.26 kg	-
Water production	10.22 kg	8.8 kg
Compressor power demand	6.37 kW	No compressor used

- From the results, we can see that the calculated and simulated values have slight differences and this could majorly be due to the various parameters that are calculated by GT-Suite simulation (such as temperature, wind speed, etc), that we have not considered for theoretical calculation.
- The team chose heliox instead of air as heliox has a lesser density than air and this allows the vehicle to reach higher speeds more efficiently and with a lesser negative impact on the system as a whole.
- The simulated values are depictive of the performance of the vehicle in the real world and we can see that when we compare them to the calculated values, the simulated values are a bit lesser and this is due to losses and other factors acting on the vehicle.
- The heat production was constant in the simulated values which shows very high efficiency of cooling which is what Ford was able to achieve by using ice water in their system to rapidly dissipate the heat at these very high speeds.

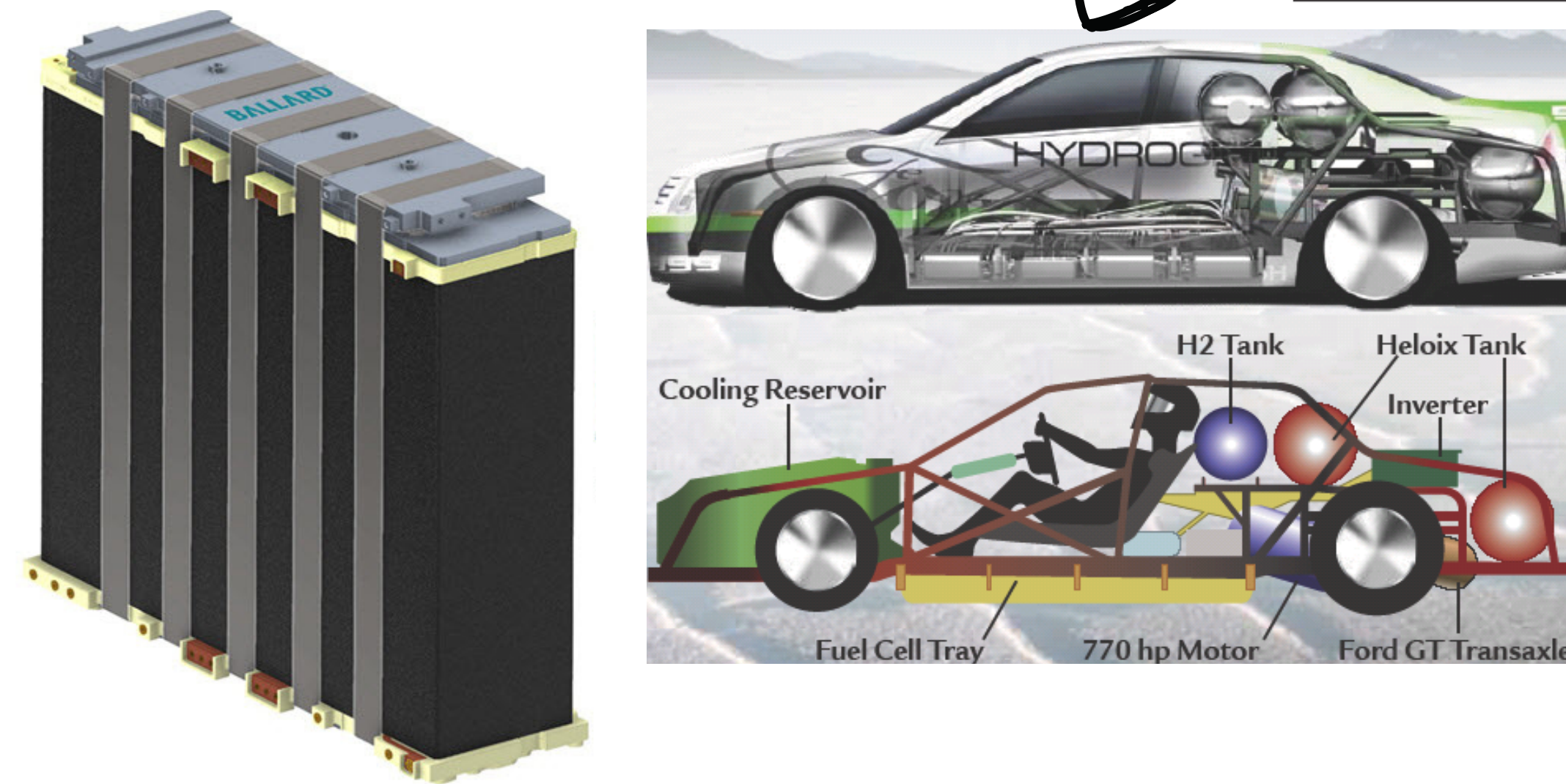
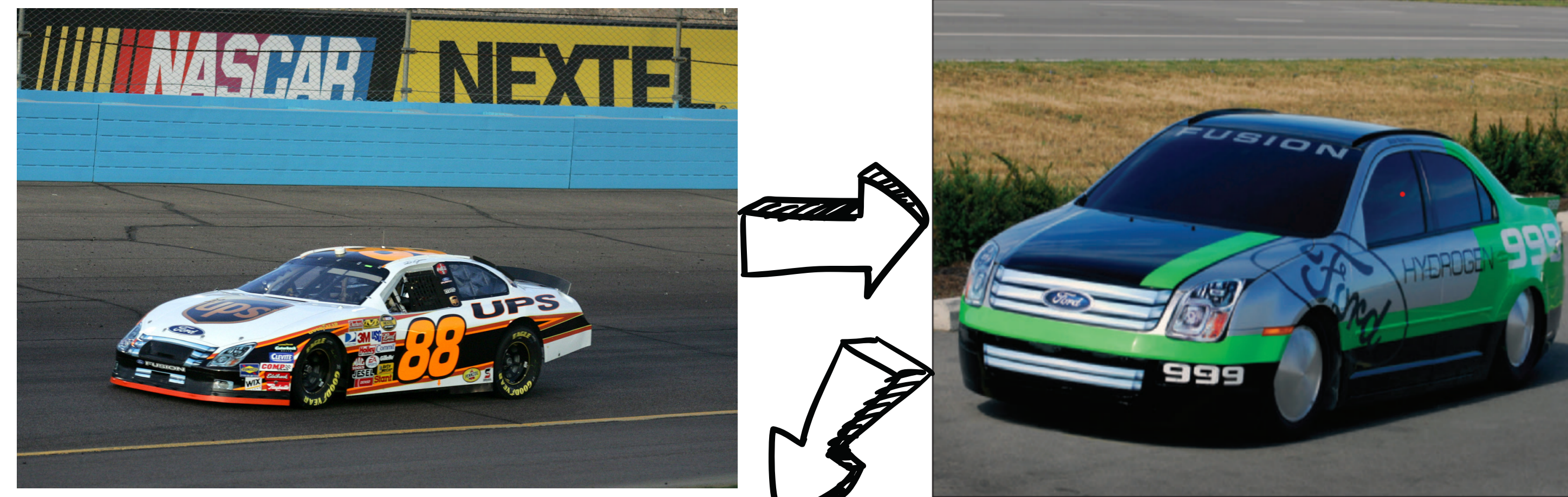
Modes of run	Required fuel	Average run time	Remarks
Anode: Hydrogen Cathode: Heliox + Oxygen (Air)	5.26 Kg	~12 mins (11.78 mins)	Theoretical/ not simulated
Anode: Hydrogen Cathode: Oxygen (Air)	1.16 Kg	~7 mins (6.3 mins)	Simulated

6. REFERENCES

- <https://www.caranddriver.com/news/a15152176/ford-fusion-hydrogen-999-car-news/>
- <https://www.greencarcongress.com/2007/08/hydrogen-fuel-1.html>
- <https://www.sciencedirect.com/science/article/pii/S1464285907703723>
- Images from Google Images

2. WHAT THE PROJECT IS ABOUT?

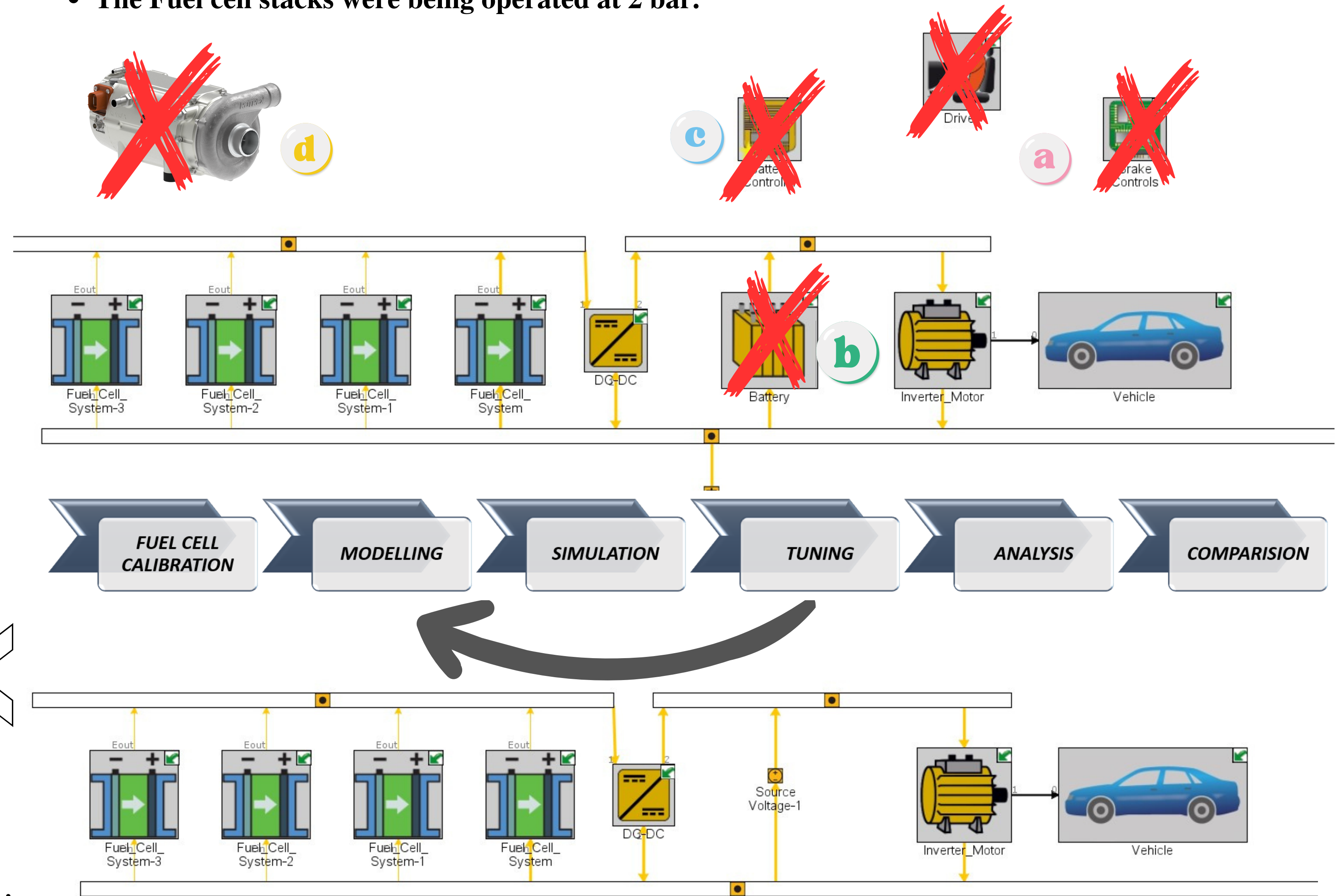
In this project, we aim to simulate the top speed run of Ford Focus 999's record-breaking run in GT-Suite and try to understand the working principles behind it and compare it to the actual run at the Bonneville Salt Flats where Ford used Heliox as opposed to oxygen from the atmosphere, unlike a regular fuel cell vehicle. We would like to understand the reasoning behind this approach and how it impacts the performance of the vehicle.



3. APPROACH

For our model we have made a few assumptions & simplifications to make the simulation process easier :

- The ambient temperature and Fuel cell stack temperature were set to the same to have the best efficiency (The team used ICE water for this purpose) and to simplify the model further.
- The stoichiometric ratios of air and fuel were 1.85 & 1.65 respectively based on the data available.
- The Fuel cell stacks were being operated at 2 bar.



a) We have also eliminated the driver control as we are not simulating a driving cycle, rather we are simulating by keeping the accelerator pedal position at 100% and the brake pedal at 0%.

b) The battery pack and c) battery controller were also eliminated as these don't exist in the real car.

d) The compressor was removed as we wanted to simplify the model further and run it at a higher efficiency.

5. LEARNING OUTCOMES & FUTURE SCOPE OF WORK

- We were able to replicate the Ford Focus 999 model in GT suite and we were able to simulate its top speed run while learning about its fuel and air consumption to achieve the targetted top speed.
- We also found out about the differences between traditional air and hydrogen being fed into the system as opposed to heliox and hydrogen along with ice water for cooling.
- Tuning and optimising a model in GT suite to perform a top speed run and debugging the analysis and model step by step to achieve our end goal.

The top speed run simulated using GT Suite as part of the system-level modeling of the Ford Fusion Hydrogen 999 showed that a hydrogen powered car can reach amazing top speed. However, the simulation results also showed that the car's powertrain might need to be optimized for high-speed driving conditions.

- These results can be used to optimize the car's powertrain for high-speed driving conditions, improve its fuel efficiency, and enhance its overall performance. The simulation results can also be used to develop and test new control strategies and technologies for hydrogen fuel cell-powered cars.
- We, as a team could simulate on making the Heliox-Oxygen air supply to work & have a better understanding of how the Ford team fine tuned the car for the run.